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GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

NASA TMX 50885

APPENDIX F
MSFC AUTOMATION PLAN

National Aeronautics and Space Administration

NASA

MLO – Holcomb

MSFC - Form 454 (Revised September 1961)

May 8, 1962

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

MSFC AUTOMATION PLAN

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(NASA TM X - 50885

Prepared By:

TECHNICAL STAFF
MSFC AUTOMATION BOARD

National Aeronautics and Space Administration

NASA

MSFC - Form 454 (Revised September 1961)

MSFC AUTOMATION PLAN

ABSTRACT

A concept to automate test and checkout operations to the maximum feasible extent for Saturn-class vehicles is presented. Preliminary information regarding the implementation of the automation concept is also given. Operations at manufacturing plants, at stage assembly areas and, particularly, at the launch sites are covered.

Lack of information concerning proposed static test facilities and operating plans prevents detailed attention in this report to the problems of utilizing automated checkout equipment at captive test sites. However, the same equipment and procedures will be utilized wherever possible at the static test sites as at other stage checkout sites.

The report was compiled by the technical staff of the MSFC Automation Board from briefings for the Director, Integration and Checkout, Office of Manned Space Flight, NASA; the General Electric Company; and MSFC stage contractors. The following persons participated in the briefings:

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MSFC AUTOMATION PLAN

Prepared

by the

Technical Staff
of the
MSFC Automation Board

MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

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LIST OF ILLUSTRATIONS (con'd)

DEFINITIONS

Automatic Data Processing System (ADPS) - A central, digital computer-controlled data retrieval and storage system, offering wide flexibility in the type of data processed. It features automatic random access from numerous remote inquiry stations.

Automatic Support Equipment (ASE) - Digital computer-controlled ground support equipment.

Central Launch and Flight Instrumentation Center - The instrumentation center associated with complex 39 at Cape Canaveral. It will be equipped to receive and transmit all RF data associated with either prelaunch or postlaunch operations at the complex. The center will be electrically linked via coaxial cables and "hard wires" to the Launch Control Operational Center and its satellite control centers.

Digital Data Acquisition System (DDAS) - A digital telemetry system designed by MSFC for "onboard" data acquisition, transmission, and subsequent processing by ground equipment for presentation and evaluation.

Electrical Automatic Support Equipment (EASE) - Automatic support equipment whose operations primarily relate to the control or monitoring of vehicle components by electrical or electronic means.

Electrical Support Equipment (ESE) - Conventional (non-digital-computer-controlled) ground support equipment whose operations primarily relate to the control or monitoring of vehicle components by electrical or electronic means.

Failure Effect Analysis (FEA) - Qualitative analysis of the effect of individual component failure on subsystem or system performance, and the subsequent effects on stage and vehicle performances.

Ground Support Equipment (GSE) - Any equipment external to a space vehicle which is used to fuel, stimulate, activate, test, checkout, launch, monitor or otherwise control or influence vehicle systems performances during prelaunch, launch, and postlaunch operations. The term covers equipment utilized for any of the above purposes at stage fabrication sites, at static test sites, and at vehicle assembly areas as well as at the launch site.

DEFINITIONS (con'd)

Instrument Unit (IU) - In Cl and C5 vehicles, the segments of the vehicles which contain the principal guidance and navigation components.

Launch Control Operation Center - The central launch control center associated with complex 39. From the center, all launch operations, manned or unmanned, will be controlled.

Launch Vehicle Control Room - A control room at complex 39 from which launch vehicle performance will be most closely monitored during launch operations. Vehicle checkouts while on the launching pads, but prior to actual launch operations, will be carried out from the control room.

Operational Computer - At complex 39, the identical computers, either located on the transporter/launchers or adjacent to the launch vehicle control room, which are used to individually or jointly handle the operational measurements and controls of launch vehicles.

Operational Computer Complex - The combination of an operational computer and certain input-output equipment used on each transporter/ launcher at complex 39. During launch operations, control of the operational computer complex is remoted through a data link from the operational computer associated with the launch vehicle control room.

Qualification Equipment - Distinct ground support equipment utilized in qualifying vehicle stages or systems prior to vehicle assembly but not required at the launch site.

Stage Computers - Digital computers associated with the automatic support equipment used in stage checkout operations.

MSFC AUTOMATION PLAN

SECTION I. TECHNICAL PLAN

A. DEVELOPMENT PLAN FOR THE C1 AND C5 VEHICLES

Before the details of the MSFC Automation Plan are explored, MSFC's philosophy in regard to design control should be briefly considered. Consideration should also be given to the basic development plans and schedules for the C1 and C5 vehicles.

The chief design emphasis at Marshall is on developing truly integrated vehicle designs as opposed to the designs that result when space vehicles are developed through makeshift marriages of individual stages. To assure straightforward vehicle designs when individual stage design and development efforts are being simultaneously carried on at widely-scattered locations, MSFC exercises controls such as the following:

a. Specific design requirements are stipulated when a stage contract is let. While due regard is given to current state of the art developments when the design requirements are established, every effort consistent with sound planning is made to avoid duplication of R&D efforts between stage contractors and between contractors at MSFC. For example, the exploding bridgewire system developed for the C1 vehicle by the Douglas Aircraft Company was stipulated for the C5 vehicle. Similarly, the MSFC-developed digital data acquisition system (DDAS) will be utilized in both the C1 and C5 vehicles (probably excluding the S-IV stage of the C1).

b. Each stage contractor is required to submit contractually-specified design documents for review and approval by MSFC in accordance with the following milestones:

(1) Detail concept release

(2) Release for fabrication

(3) Release for production

(4) Start of stage systems checkout.

c. MSFC controls and documents all interface areas external to any stage. Every effort has been made to avoid interface complications through standardized design practices. For example, power from one stage is not used to actuate relays in another; instead, power from the stages in which relays are located is routed through necessary relay or switch contacts in other stages and then routed to the relays.

d. MSFC develops the C1 and C5 guidance and control systems, including many of the components involved. Consequently, MSFC designs the instrument units for its vehicles. Tight control can therefore be exercised, for example, over propulsion stage hydraulic actuation systems. Similarly, the instrument unit provides a central source for sequencing functions and for system control signals, which greatly reduces potential interface hazards.

e. MSFC is carrying out design efforts associated with the automation of C1 vehicle checkout operations. The same procedures and techniques will be utilized to integrate launch-site automatic support equipment (ASE) for the C5 program.

The following tabulation shows development responsibilities and status for the C1 and C5 programs.

a. C1 Vehicle (Block II) (Figures 1 through 4)

(1) S-I Stage — Detailed design virtually completed by MSFC.

(2) S-IV Stage — Detailed design virtually completed under MSFC direction by Douglas Aircraft Company.

(3) Instrument Unit — Detailed design nearing completion by MSFC.

b. C5 Vehicle (Figures 5 through 8)

(1) S-IC Stage — Design to be carried out at Huntsville as a joint MSFC-Boeing undertaking for test vehicles. Design to be updated by Boeing Aircraft under MSFC direction for flight program.

(2) S-II Stage — North American Aviation, Incorporated, is designing the stage under MSFC direction.

(3) S-IVB Stage — Douglas Aircraft Company is designing the stage under MSFC direction.

(4) Instrument Unit — Being designed by MSFC.

c. Automatic Support Equipment for C1, Block II (Figure 3)

(1) S-I Stage and Instrument Unit — Detailed design being carried out by MSFC.

(2) S-IV Stage — Douglas Aircraft Company is carrying out design under MSFC direction. No provisions for automatic checkout are being made at present.

(3) Launch Site — Detailed design being carried out by MSFC.

d. Automatic Support Equipment for C 5 (Figure 7)

(1) Instrument Unit — Detailed design being carried out by MSFC.

(2) S-IC Stage — Design to be carried out in same manner as the stage design.

(3) S-II Stage — Design to be carried out by North American Aviation under MSFC direction. Launch-site ASE will be an MSFC responsibility.

(4) S-IVB Stage — Douglas Aircraft will carry out the design under MSFC direction. Launch-site ASE will be an MSFC responsibility.

(5) Launch Site — To be developed by MSFC using, where applicable, equipment developed for stage checkout. The system will be integrated with an eye to utilizing standard components wherever possible. Important objectives are to undertake a minimum of hardware development and to enhance reliability through simplified design. By assuming responsibility for all launch site ASE, MSFC eliminates the divisions of responsibility for launch-site operations that have hindered many programs. A key benefit of having only one organization accountable for launch-site ASE is that design can be completed relatively late in the program, thus resulting in a minimum of modification and a more efficient design.

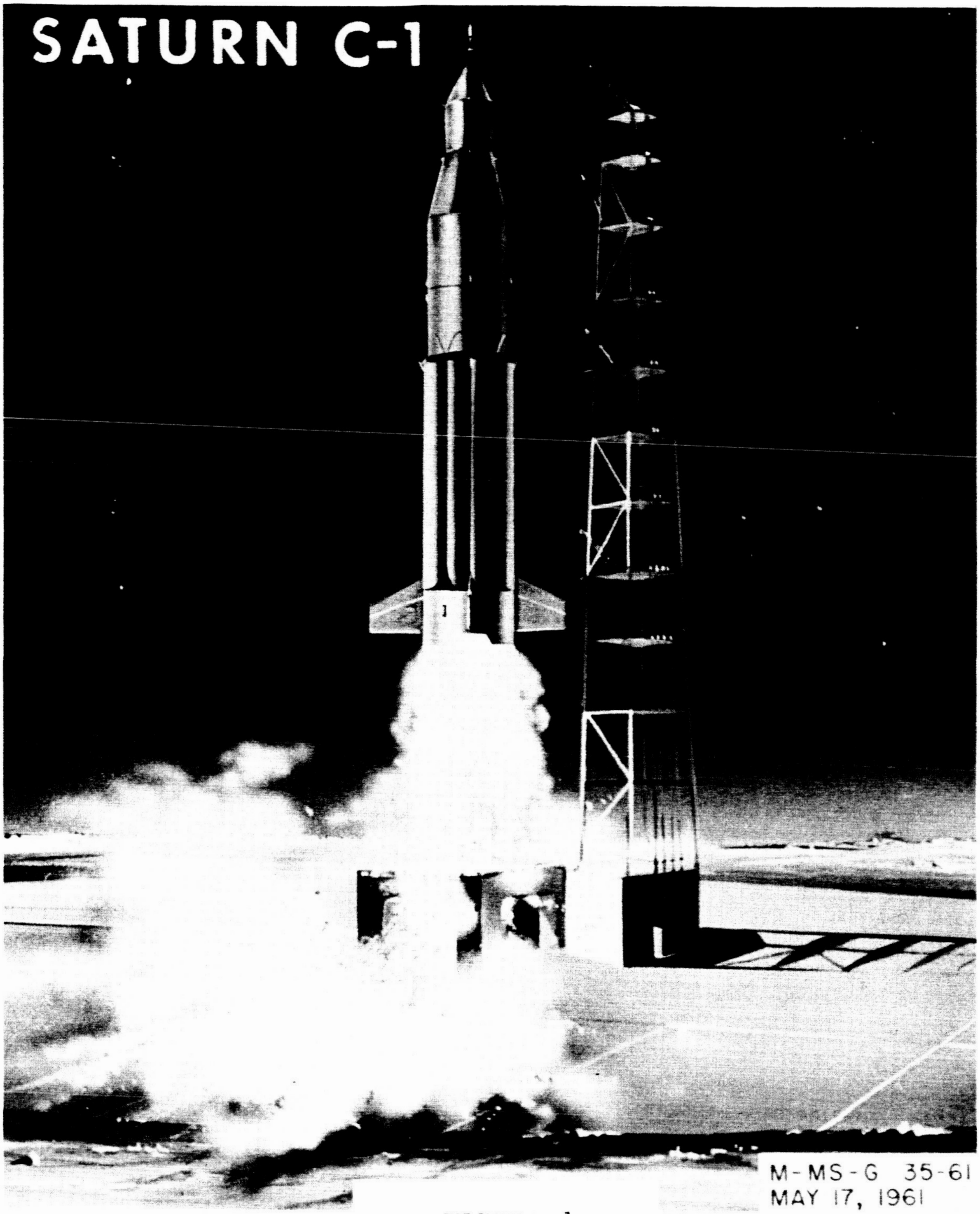


FIGURE 1

C-I VEHICLE FLOW DIAGRAM

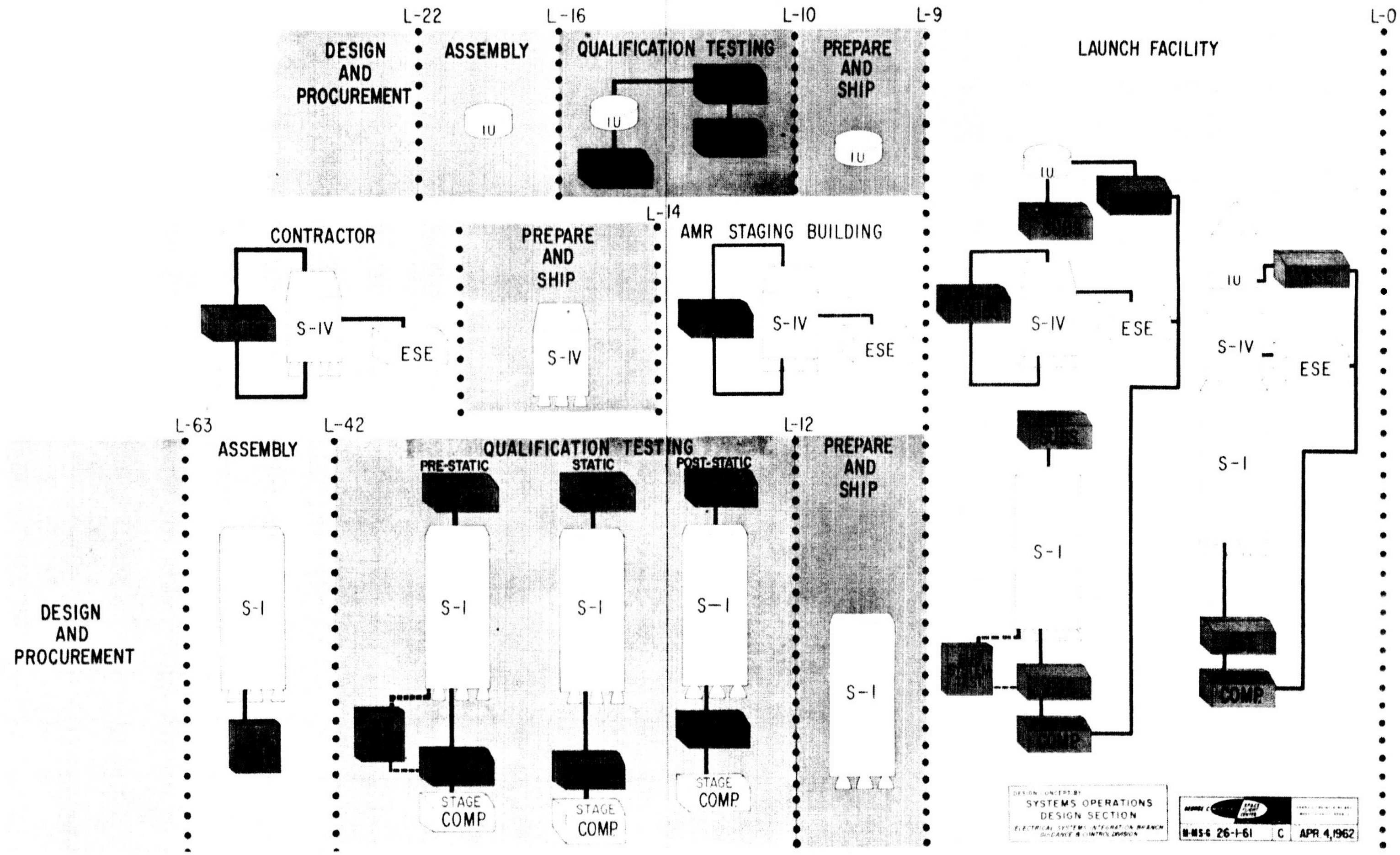


FIGURE 2

DEVELOPMENT SCHEDULE
C-I SUPPORT EQUIPMENT

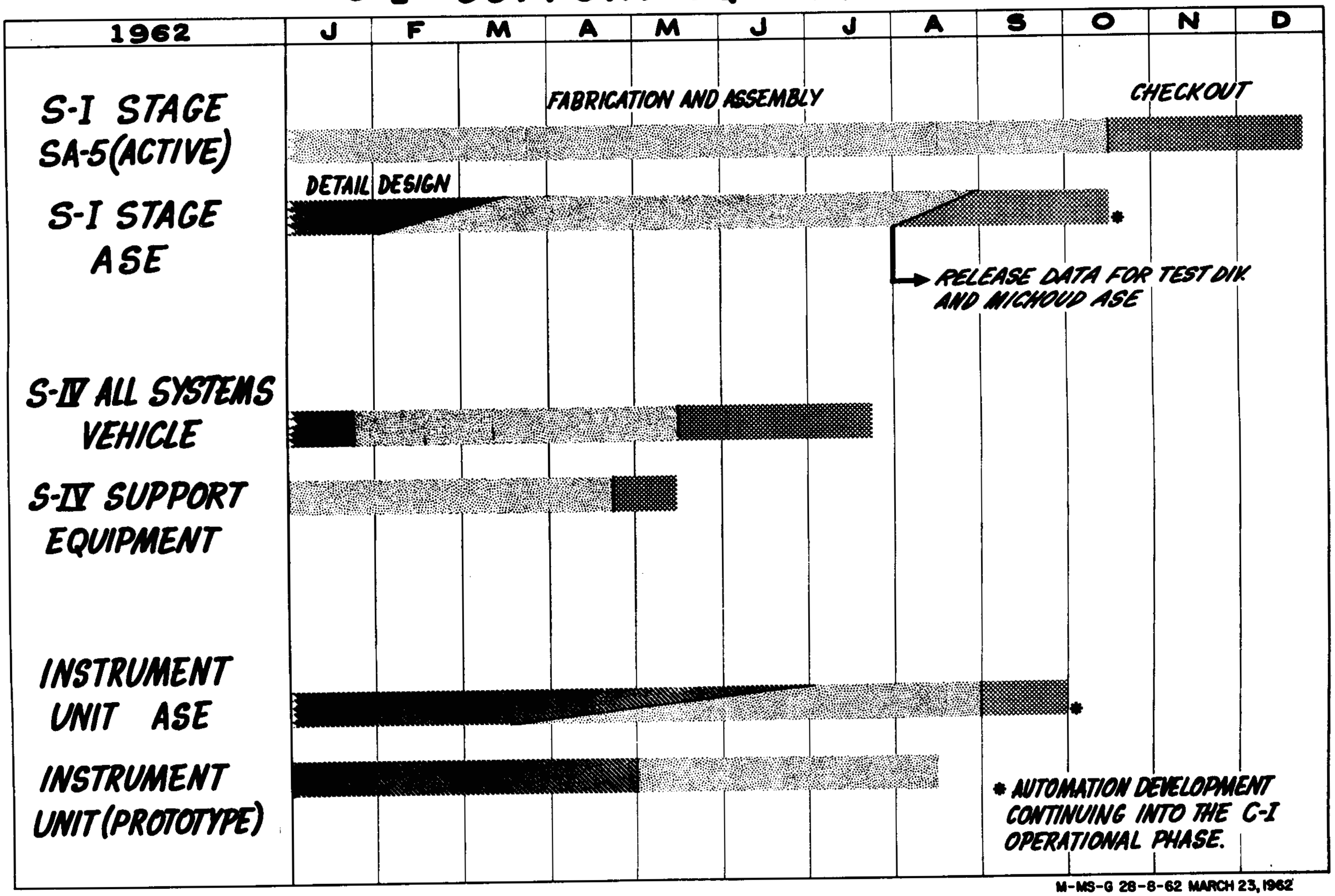


Figure 3.

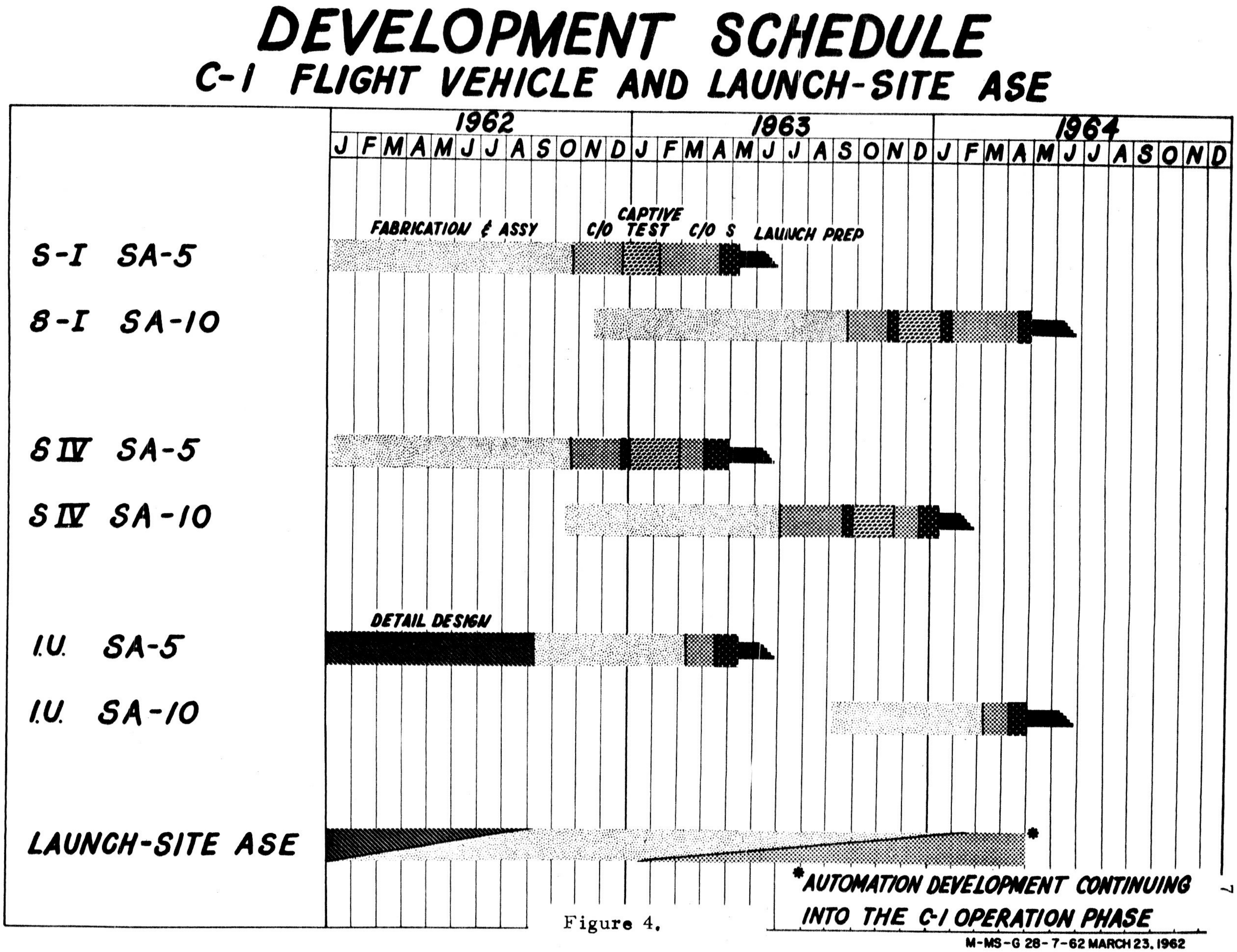

DEVELOPMENT SCHEDULE
C-I FLIGHT VEHICLE AND LAUNCH-SITE ASE
1962
1963
1964
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
FABRICATION & ASSY
C/O
CAPTIVE TEST
C/O S
LAUNCH PREP
S-I SA-5
S-I SA-10
S IV SA-5
S IV SA-10
DETAIL DESIGN
I.U. SA-5
I.U. SA-10
LAUNCH-SITE ASE
*AUTOMATION DEVELOPMENT CONTINUING INTO THE C-I OPERATION PHASE
M-MS-G 28-7-62 MARCH 23, 1962

Figure 4.

SATURN C-5

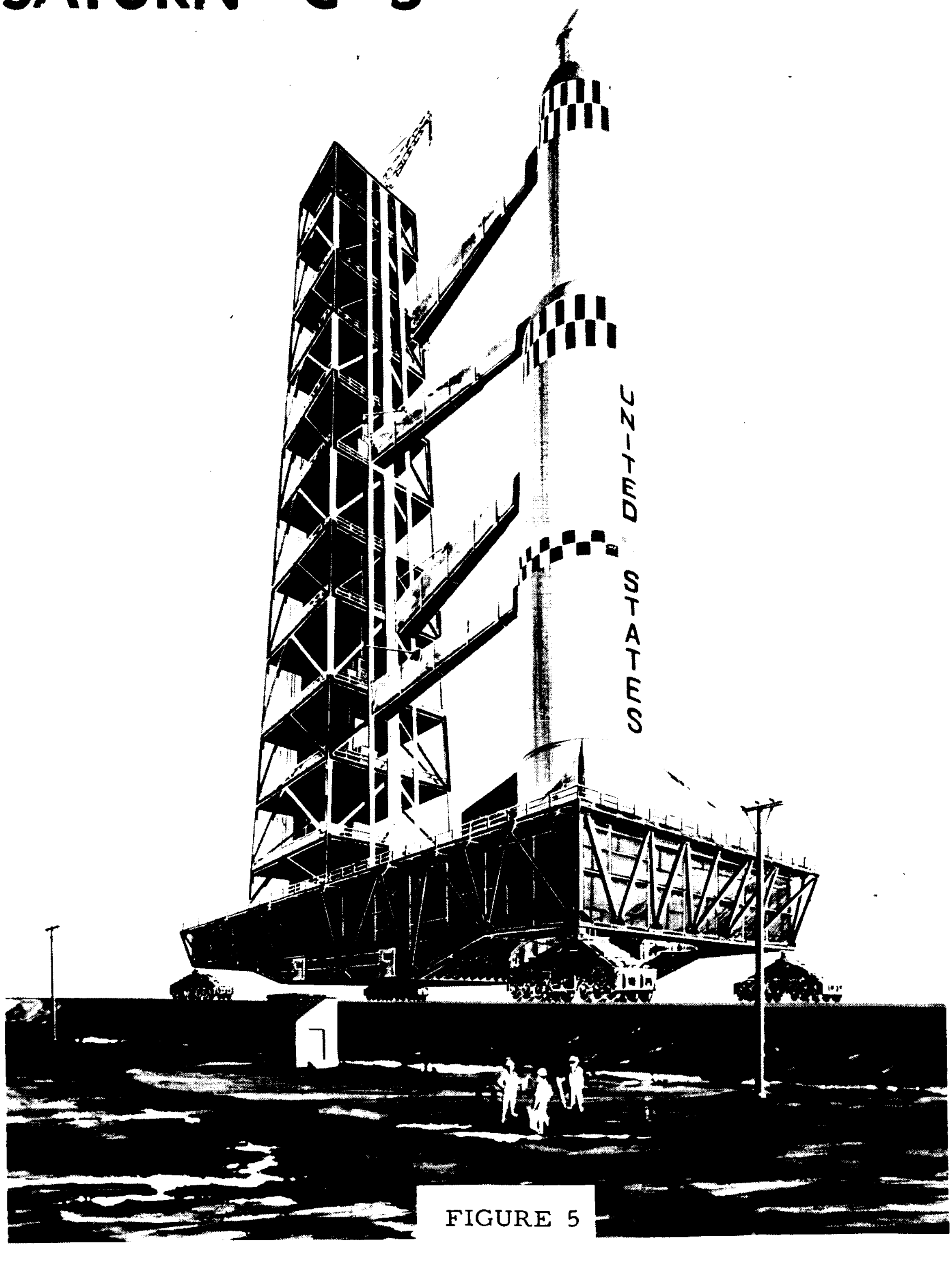


FIGURE 5

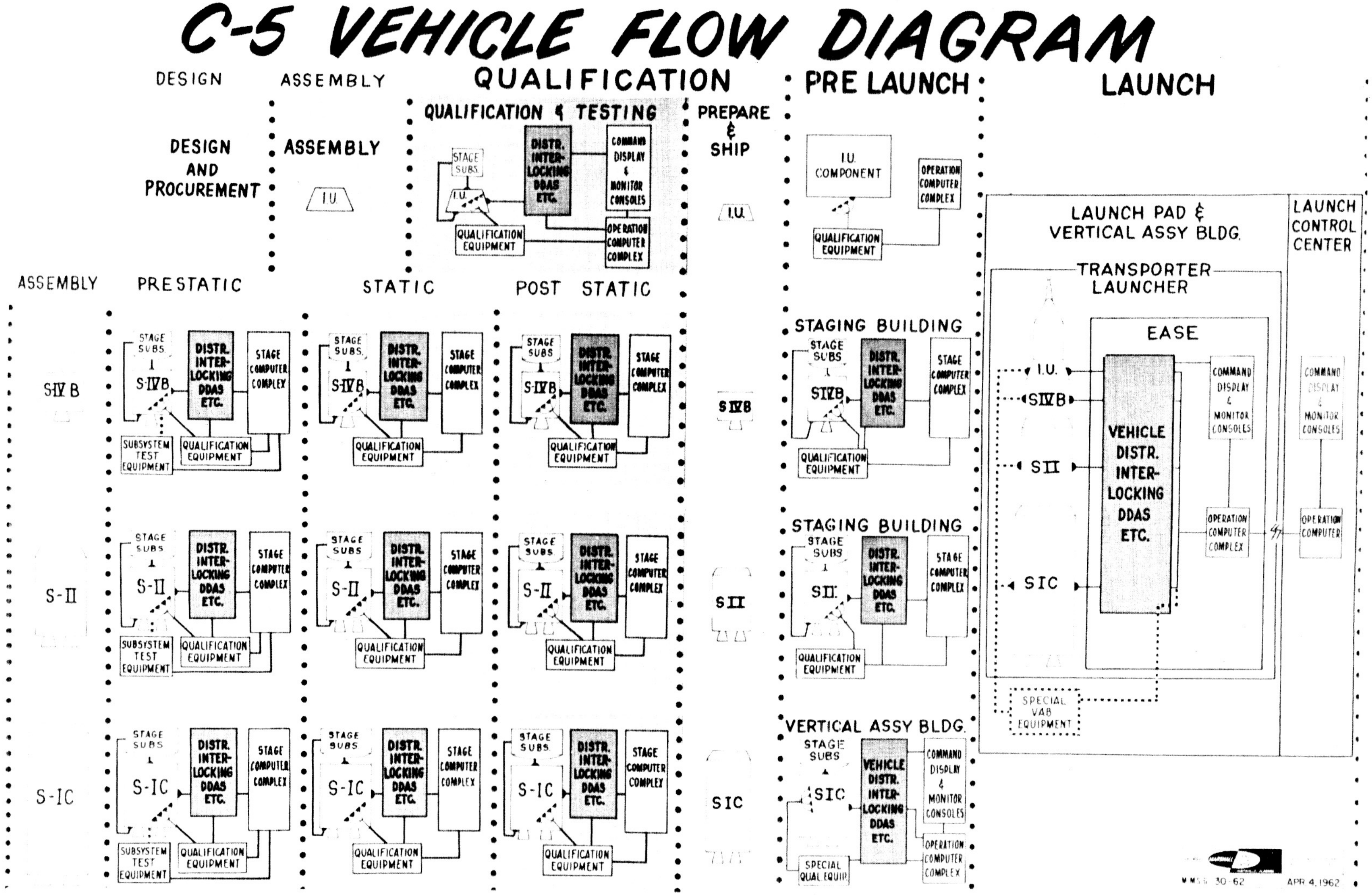

C-5 VEHICLE FLOW DIAGRAM
DESIGN
ASSEMBLY
QUALIFICATION
PRE LAUNCH
LAUNCH
DESIGN AND PROCUREMENT
ASSEMBLY
I.U.
QUALIFICATION & TESTING
STAGE SUBS
DISTR. INTER-LOCKING DDAS ETC.
COMMAND DISPLAY & MONITOR CONSOLES
QUALIFICATION EQUIPMENT
OPERATION COMPUTER COMPLEX
PREPARE & SHIP
I.U. COMPONENT
ASSEMBLY
PRESTATIC
STATIC
POST STATIC
S-IVB
S-II
S-IC
STAGE COMPUTER COMPLEX
SUBSYSTEM TEST EQUIPMENT
STAGING BUILDING
VERTICAL ASSY BLDG.
VEHICLE DISTR. INTER-LOCKING DDAS ETC.
SPECIAL QUAL EQUIP
LAUNCH PAD & VERTICAL ASSY BLDG.
TRANSPORTER LAUNCHER
EASE
SPECIAL VAB EQUIPMENT
LAUNCH CONTROL CENTER
OPERATION COMPUTER
APR 4, 1962

FIGURE 6

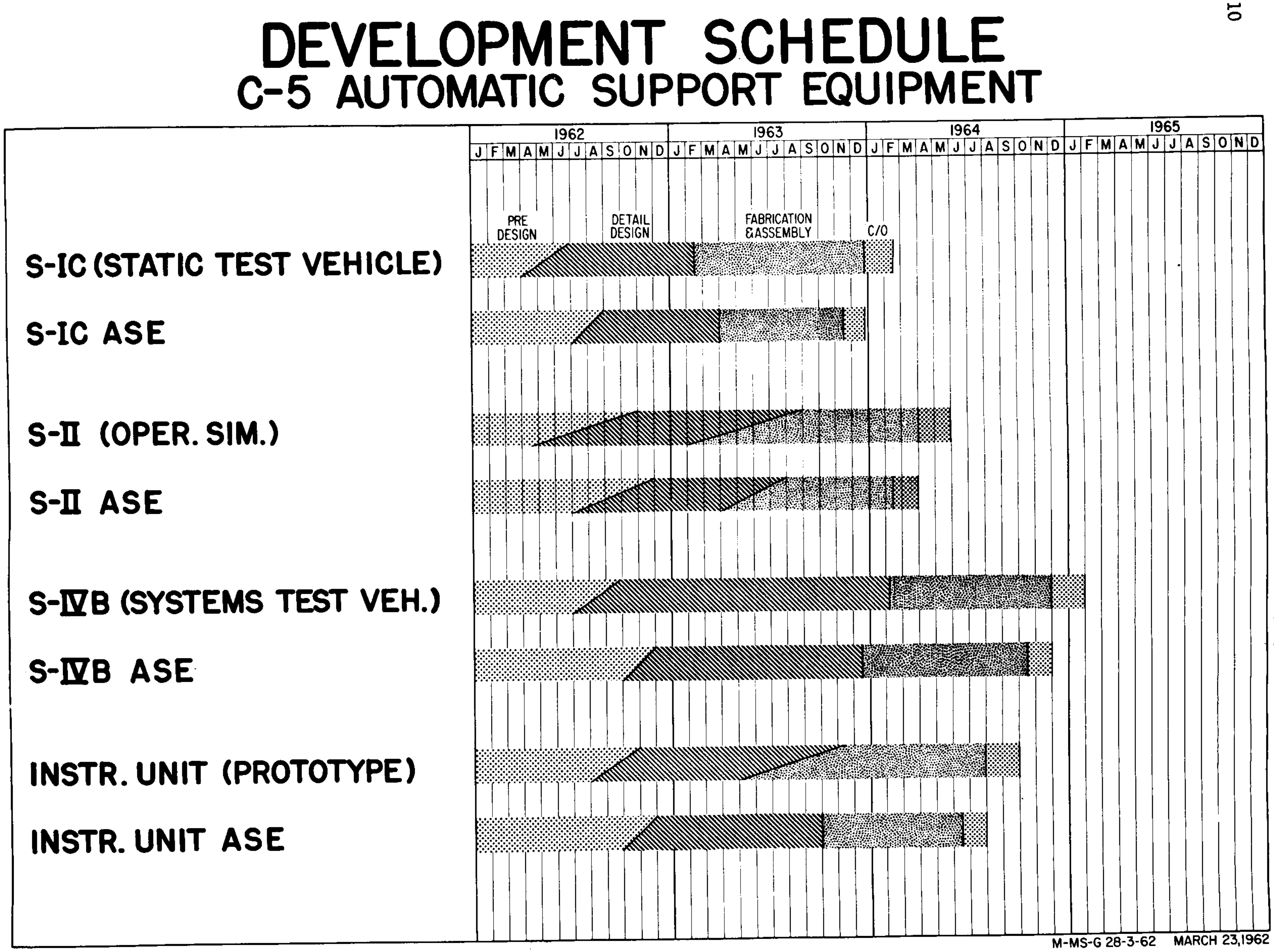

DEVELOPMENT SCHEDULE
C-5 AUTOMATIC SUPPORT EQUIPMENT
1962
1963
1964
1965
J F M A M J J A S O N D
PRE DESIGN
DETAIL DESIGN
FABRICATION &ASSEMBLY
C/O
S-IC (STATIC TEST VEHICLE)
S-IC ASE
S-II (OPER. SIM.)
S-II ASE
S-IVB (SYSTEMS TEST VEH.)
S-IVB ASE
INSTR. UNIT (PROTOTYPE)
INSTR. UNIT ASE
M-MS-G 28-3-62
MARCH 23,1962

Figure 7.

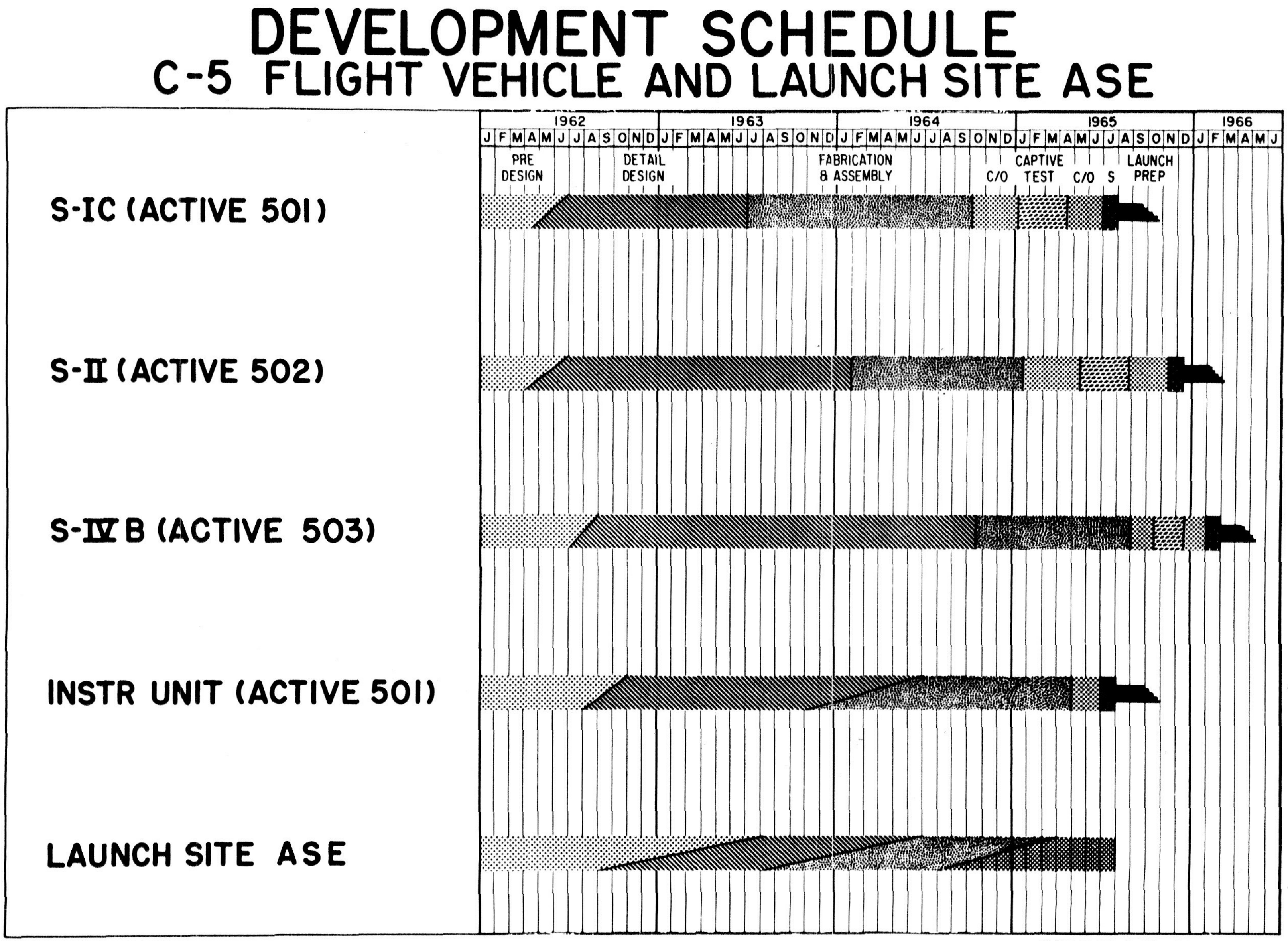


Figure 8.

M-MS-G 28-4-62 MARCH 23, 1962

In qualifying a vehicle stage, substitutes for the other stages and for the instrument unit must be utilized. Similarly, stage substitutes must be employed while the instrument unit is being checked out. The term, stage interface substitutes, is used to describe such equipment.

In the C1 program, each stage manufacturer was originally expected to furnish stage interface substitutes for use at other checkout sites. MSFC, as the instrument unit contractor, has furnished instrument unit substitutes for all stage checkout sites. While suitable for C1, such arrangements can clearly become burdensome in ever-changing R&D programs for multi-stage vehicles.

For the C5 program, MSFC does not plan to require each stage manufacturer to furnish and continuously update the numerous stage interface substitutes that the program will require. Instead, each manufacturer will be expected to furnish MSFC with documentation of its interface requirements. In turn, MSFC will coordinate and pass on such requirements to the other contractors involved. Each manufacturer will then fabricate interface substitutes as its needs require.

Where necessary, each stage manufacturer will be given specific parts lists for equipment in other stages in order that essential system functions can be duplicated or simulated. In addition, MSFC will furnish flight control amplifiers for use with each stage manufacturer's interface substitutes.

Obviously, the C5 program will see many changes made in interface documentation. As has been pointed out, MSFC will rigidly control such changes in order to assure, among other things, that reliable and functionally compatible stage interface substitutes are used at all stage checkout sites.

Stage interface substitutes for the S-IV stage of the C1 program will be fabricated in accordance with the concept described for the C5 program. However, the interface substitutes already stipulated in the cases of the S-I stage and the instrument unit will be utilized at all S-IV stage checkout stations.

MSFC has requested the S-II and the S-IVB contractor to analyze their interface requirements and to propose detailed methods for developing stage interface substitutes. Both contractors are in general agreement with the concept outlined here. A mutually acceptable and detailed concept will be developed for the entire C5 program after the two stage contractors' proposals are reviewed.

The foregoing remarks bring out the advantages of having the C1 and C5 instrument units as separate segments of the vehicle. For example, if the equipment associated with the instrument unit were to be installed in a propulsion stage, the definition of the equipment would have to take place approximately 6 months earlier than is the case with a separate instrument unit.

Several advantages accrue from being able to withhold instrument unit definition until mission requirements can be detailed. A late design freeze is made possible. Several instrument packages can be made available for various missions, thus allowing selection of the proper one for a given operation to be made at a late date.

At this point, it should be noted that the degree to which the Douglas S-IV stage will be adapted to automated checkout operations will depend on a forthcoming decision regarding the extent of utilization of the stage in future programs. For the time being, there are no plans to undertake significant design modifications of the stage as far as automatic checkout systems are concerned.

B. LAUNCH-SITE AUTOMATION CONCEPT

With any automatic space vehicle checkout system, the primary missions are to determine the vehicle status and to pinpoint troubles when they occur. Computer-controlled automatic checkout equipment offers speed, accuracy and versatility — characteristics that are necessary for the successful completion of either type of test. The main advantages of such a system are improvements in vehicle systems reliability and savings in time required for the many phases of testing and launch preparation.

The human being is a poor observer. He tends to make errors in exact operations. He responds slowly and cannot retain large amounts of rapidly presented data. The computer system can do all of these well. The man, however, is very good at such things as selecting the best means of handling an unexpected situation, originating new ideas and solutions to problems, diagnosing symptons, and making decisions based on previous results under similar situations. The above comparison obviously implies that some man-machine combination is ideal for checkout operations. In the case of the C5 vehicle, the requirement for remote operations further enhances the argument for automation of checkout operations. Using such a system, standardization of testing methods throughout the vehicle test program can be more nearly accomplished. Complete test results can be logged with ease and made available for design improvement studies.

Since component running times during automated testing procedures will be cut to minimum levels, the effective mean-time-to-failure for the vehicle will be increased. Once a system is correctly automated, testing of a thorough nature can be done in much less time than in the manual case. Accordingly, the confidence of launch personnel in the flight hardware can be increased. When a system failure has been noted, the exact condition under which that failure occurred can be easily duplicated. More complete data can be gathered at the instant of failure to aid in trouble-shooting and fault isolation.

In military systems of the past, automation has suffered because of operation and environmental requirements which have dictated that the launch checkout equipment be simplified to the greatest possible degree. The complicated and more versatile equipment has been reserved for rear area testing. In the case of Saturn, this requirement does not exist. Personnel of engineering caliber will operate and monitor the launch equipment in an engineering atmosphere. The tools that these personnel have available should be on a par with their capabilities. The machine portion of this man-machine team must therefore be versatile, powerful, and in no way restrict (but rather increase) the man's confidence in the status of the complicated countdown and checkout procedure. The introduction of additional automatic launch hardware adds some complexity to the operational equipment. This complexity is undesirable and should be kept to a minimum. In many automation efforts, complexity has been greater than necessary. As a result, the task of "selling" potential users has been made more difficult.

Adequate learning time must be provided so that operation personnel may gain confidence in the hardware and concepts. The operating personnel training must not be neglected and the operators must not lose touch with the hardware and processes as a result of automation. Automation in a checkout operation is a tool to help the operator — not a substitute for his skill and knowledge.

An area that must be considered a major problem is the generation of hardware checkout programs. More than one program has resulted in capable, but ignorant, checkout hardware. Programs must be developed over a period of time as hardware and testing procedures are developed. An adequate program requires extremely close coordination between machine programers, hardware designers, system designers, and the user. The full capabilities and limitations of the automatic checkout systems and the vehicle systems involved must be considered.

Reliability is a prime requirement of any checkout system. The hardware and testing procedures must be selected with reliability high on the list of requirements. The state of the art in various types of checkout equipment, both analog and digital, has greatly improved over the last few years. It is now possible to obtain very reliable conversion and processing equipment for use with digital intelligence equipment. Consequently, a checkout system made up of commercially available equipment which is both reliable and accurate is foreseeable in the very near future. With digital equipment, installation and checkout remain a problem; but once a system is working properly, it can be expected to continue to do so.

An automatic checkout system, using present-day digital techniques and tailored to the needs of the Saturn program, can be developed with a high degree of confidence that the system will work properly and that it will markedly improve the overall vehicle system. If this system is planned and developed properly, all personnel involved can be adequately trained and can become familiar with every portion of the total operation.

Perhaps the most underdeveloped area in automatic checkout is in the diagnosing of troubles. This is a result of inability to predict all the ways a component or subsystem may fail as well as the lack of close programer-designer-user coordination. Much can be done in this area, however, if diagnostic procedures at the launch site are limited to black boxes or subsystems and if automatic fault isolation is considered in the design of these boxes. The MSFC computer-controlled system has all the inherent characteristics required to fault isolate to the black box level or even lower; however, the flight hardware and vehicle design must include the means to monitor all critical points and the computer program must utilize these points in an efficient manner.

Computer-controlled checkout systems offer tools which allow large amounts of information to be monitored, recorded, and manipulated in almost any manner. If desirable, operators and other personnel can select portions of this information in a visual form. Displays may take many forms ranging from the typewriter or simple go no-go lamps to large multicolor screen displays for large audiences.

The Saturn program will remain essentially a research and development operation; therefore, the checkout equipment used must be flexible enough to allow its functions to be changed appreciably from one vehicle to the next. Since computer-controlled launch vehicle checkout is actually of a general purpose function, minor changes in programs can be readily accomplished on the spot. Given time, extensive program changes can be made and completely checked out without endangering reliability.

1. Automation Requirements and Vehicle Test Area Definitions

The following requirements for automatic equipment development have been generated:

a. The development must cover the Saturn programs.

b. The same technologies and, where possible, the same hardware should be used throughout the Saturn development.

c. The hardware and techniques developed must fit into the plans and facilities of both Launch Operations Center and stage testing areas.

d. Maximum possible time should be provided for personnel training and systems design proofing.

e. Proper emphasis should be given the problems of generating test programs such that hardware delivered will contain adequate and proven test programs.

Before discussing checkout configurations and plans, it is necessary to clarify certain operations and test conditions. The vehicle measurements are separated into operational measurements that are used to prepare and launch the vehicle and measurements received through telemetry that are used primarily for flight performance evaluation.

Prior to assembly into the vehicle, a stage must have met operational, measuring, and telemetry checkout requirements. In this respect, all stages must meet the same checkout philosophy requirements.

Stage interface GSE is broken into two main categories: (1) circuitry associated with the operational task and (2) circuitry used to manipulate and evaluate the measuring and telemetry hardware. Figure 9 shows the general block diagram of a stage checkout system. Here the stage and its interface GSE are connected to the checkout facility test equipment. Non-electrical stimuli, such as pressures, are fed directly from the facility test equipment to the vehicle.

To properly simulate upper and lower interfaces, stage substitutes are provided so that the entire operation of the total stage can be evaluated. Most of this operation will evaluate and calibrate the outputs of the signal conditioners contained within the stage. Shown also in Figure 9 is the RF output which will be tested and qualified as a portion of stage checkout. In future developments, this RF link can reduce the number of hard wires which travel through the stage interface GSE. Digital data acquisition equipment for such applications will be specified by MSFC.

2. Vehicle Checkout and Launch

a. Checkout and Launch Definitions

Figure 10 shows the general block diagram for vehicle countdown and launch. This diagram does not include the Central Launch and Flight Instrumentation Center (shown in Figure 15), which receives and evaluates measuring and telemetry information received via the RF link from each one of the stages. This link probably will operate through a coaxial conductor instead of radiating during prelaunch operations.

All of the operational portions of the stage interface GSE are connected to the operational and launch equipment, thus completing the circuitry required to prepare and launch the vehicle. The dotted lines in Figure 10 indicate connections to measurement stimulation equipment which may be required in some of the phases of the vehicle checkout program. (An example of this may occur when large boosters go directly to the launch site or vertical assembly facility without passing through a stage checkout building.)

As experience, hardware reliability, and user confidence grow, it should become possible to do the last complete measuring calibration when the stage is checked out just prior to its assembly into the vehicle. From this point, normal outputs would be monitored and checked by the Central Launch and Flight Instrumentation Center through the RF link.

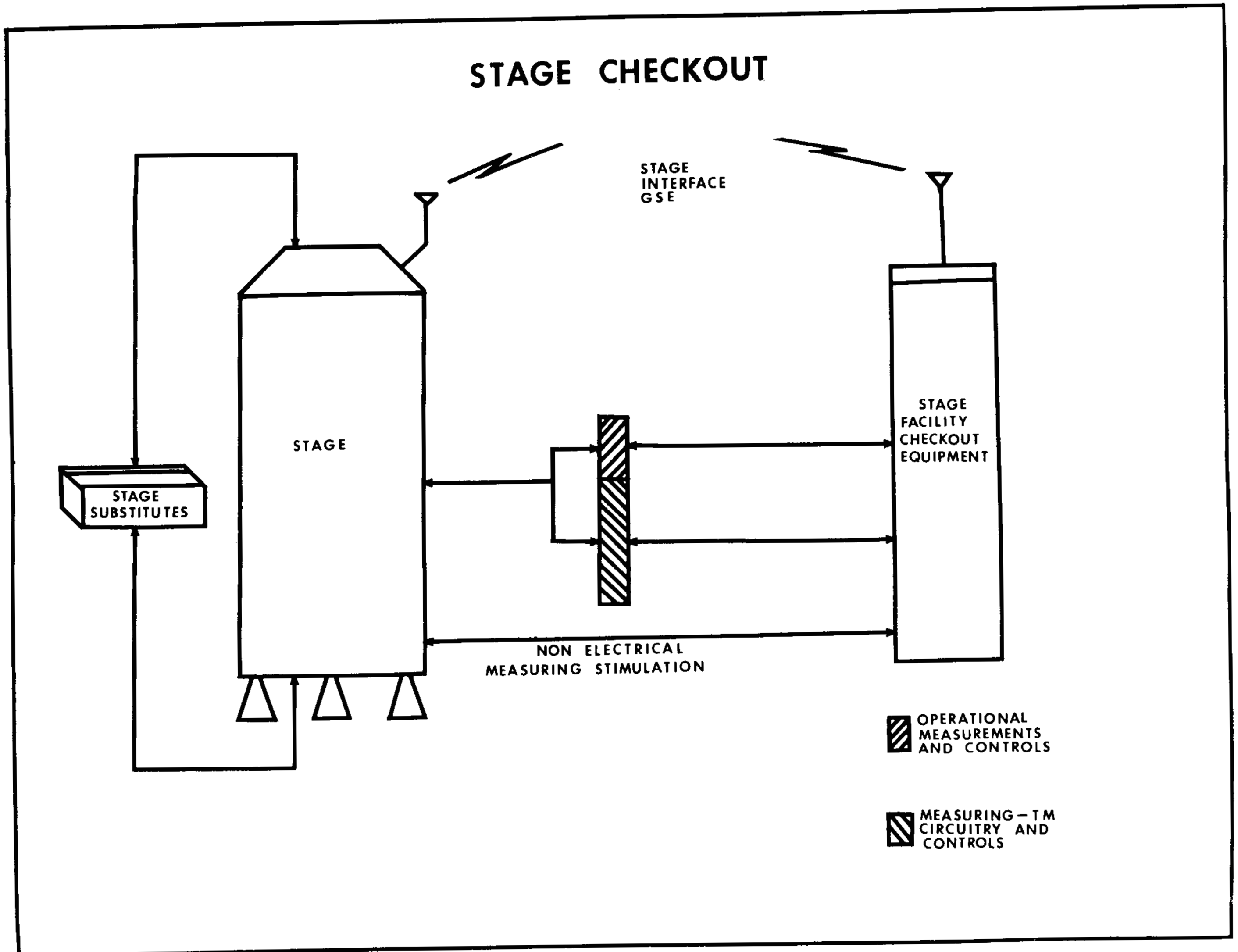

STAGE CHECKOUT
STAGE INTERFACE GSE
STAGE
STAGE SUBSTITUTES
STAGE FACILITY CHECKOUT EQUIPMENT
NON ELECTRICAL MEASURING STIMULATION
OPERATIONAL MEASUREMENTS AND CONTROLS
MEASURING-TM CIRCUITRY AND CONTROLS

Figure 9.

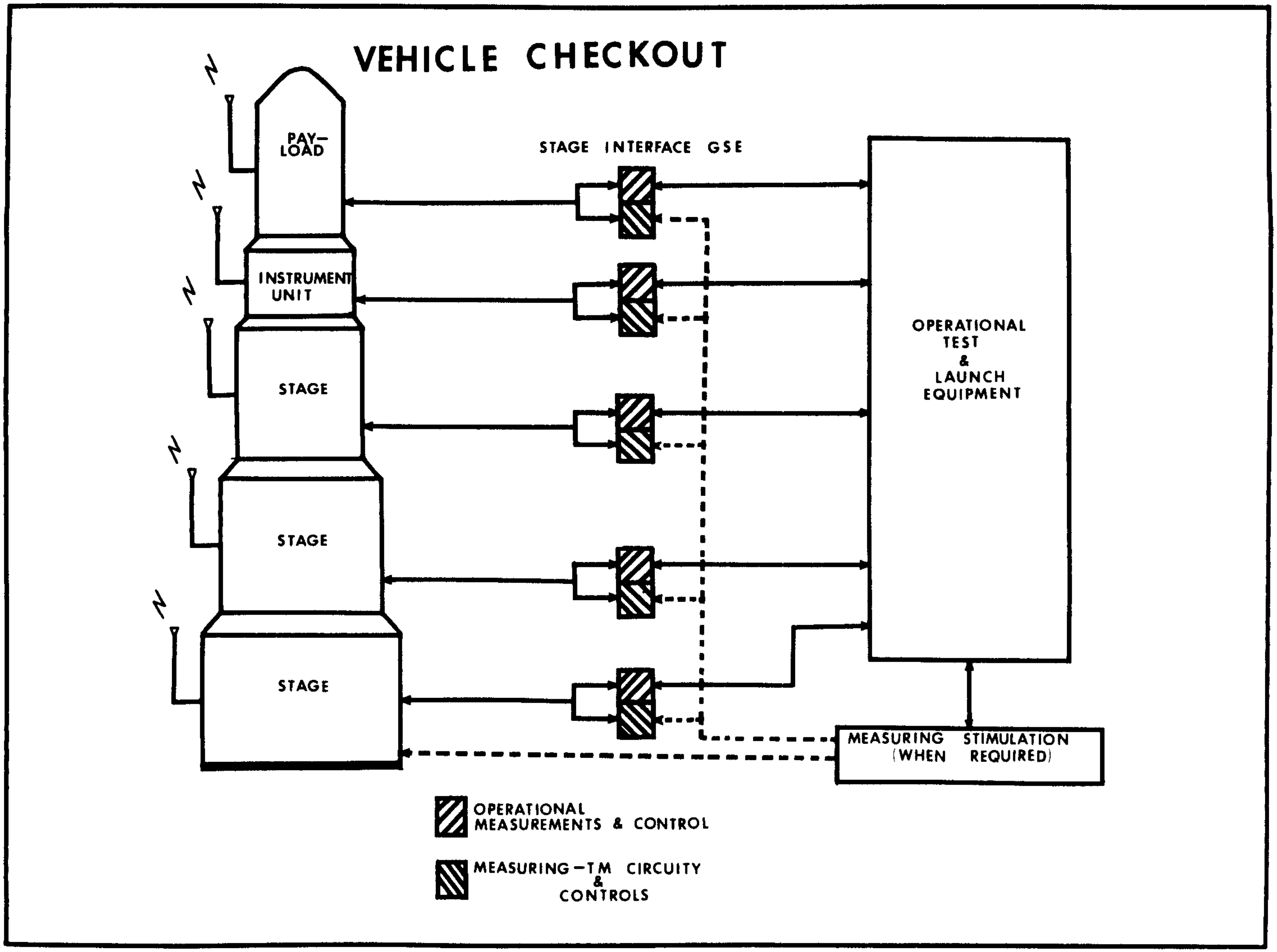

VEHICLE CHECKOUT
PAY-LOAD
INSTRUMENT UNIT
STAGE
STAGE
STAGE
STAGE INTERFACE GSE
OPERATIONAL TEST & LAUNCH EQUIPMENT
MEASURING STIMULATION (WHEN REQUIRED)
OPERATIONAL MEASUREMENTS & CONTROL
MEASURING-TM CIRCUITY & CONTROLS

Figure 10.

In the following discussion, the operational checkout hardware is presented first. After describing vehicle checkout and launch-site operations, the plans for stage checkout will be brought out to show the concept visualized for standardized automatic checkout hardware at contractors' facilities. In the area of vehicle measuring and telemetry circuits, improvements in the vehicle itself will greatly facilitate stage and vehicle checkout and calibration. One basic improvement will be a digital data acquisition system which will greatly aid the checkout problem. This system is discussed in paragraph C.

b. Operational Computer Complex

The intelligence and comparison unit to be used as an integral portion of the GSE in handling the operational measurements and controls of the vehicle system is the computer complex shown in Figures 11 and 12. The heart of this complex is a medium-size, general purpose digital computer which evolved from the basic needs for ground guidance equipment. The computer was expanded to handle the types of analog and digital information used in operational checkout and also expanded to generate the commands and data needed to preset and launch the vehicle. The best estimates presently available for inputs and outputs required in the SA-5 through SA-10 requirements are shown in Figure 12.

The particular equipment selected was obtained through competitive bids and was procured during fiscal year 1961. Since November 1960, Marshall personnel have been training on this equipment, which was designed specifically for process control with ultimate goals of highest reliability and performance. MSFC quality standards will be followed in the fabrication of launch-site equipment. This, coupled with the excellent basic design, should assure operational equipment of the highest reliability.

Some of the characteristics of the particular equipment to be used may be of interest. The computer system is the RCA-110 system. The computer itself has both core and drum storage. As shown by Figure 12, the working storage is a magnetic core memory of 4096 words; clock frequency is 936 kc. The drum is utilized for bulk storage and can be expanded to 32,768 words. The number system is fixed-point binary, using a 24-bit word length. The word length represents the best average to work with the various possible vehicle guidance computers. The computer has 70 wired-in instructions and 7 "indexable"

Operational Computer Complex

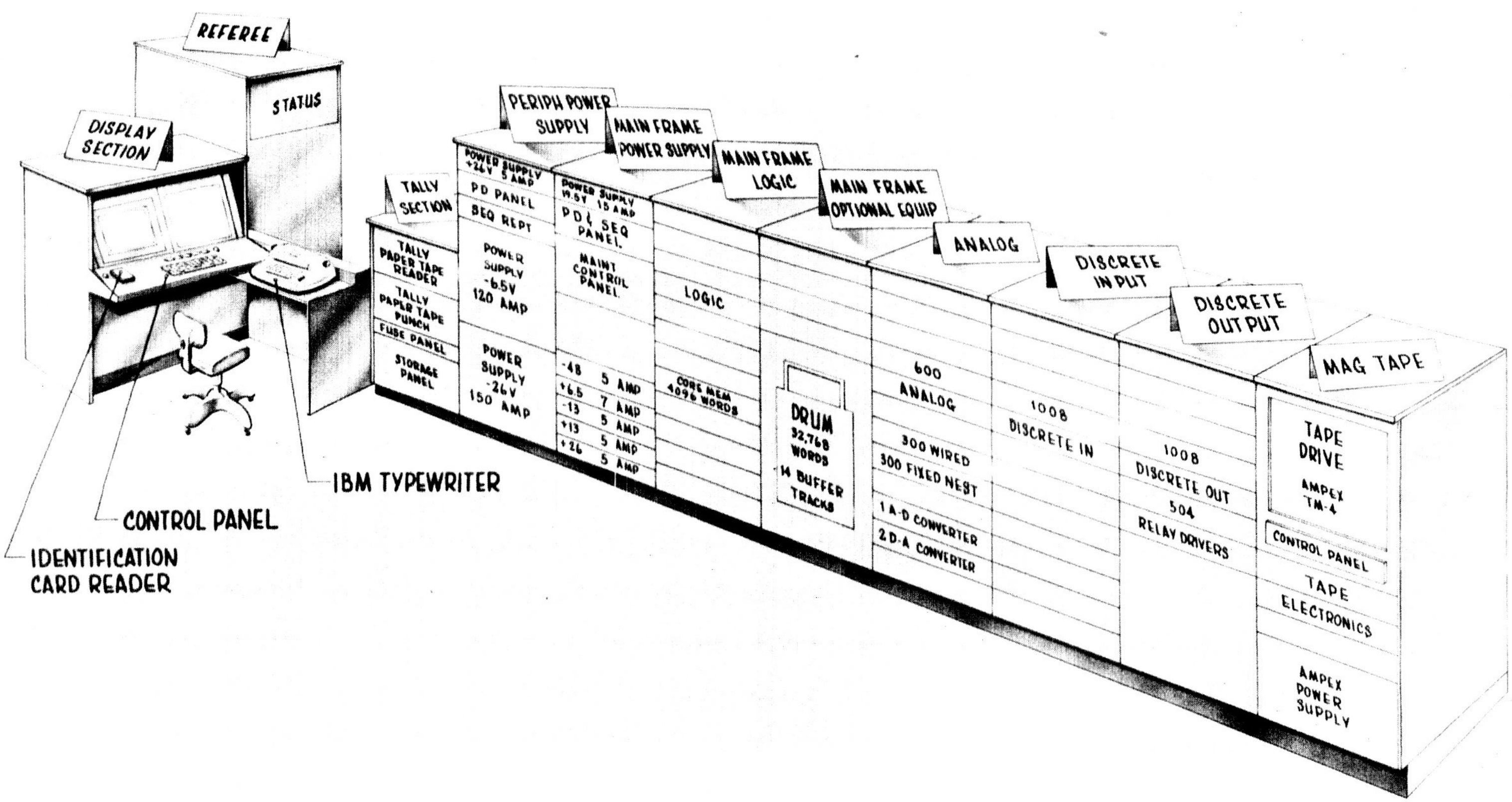


Figure 11.

MSFC MARSHALL SPACE FLIGHT CENTER
M-MS-G 28-2-62
MAR 23, 1962

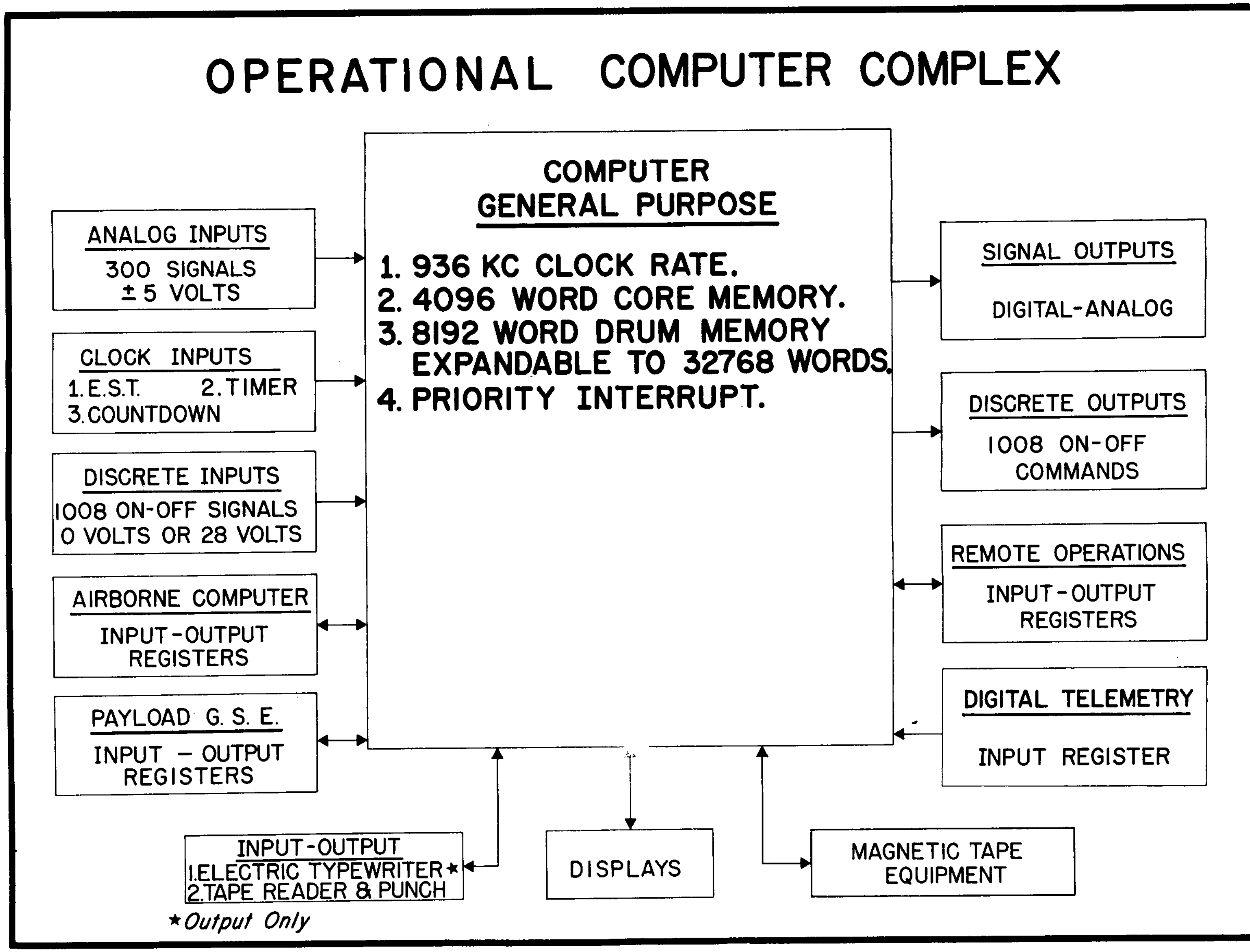

OPERATIONAL COMPUTER COMPLEX
COMPUTER
GENERAL PURPOSE
1. 936 KC CLOCK RATE.
2. 4096 WORD CORE MEMORY.
3. 8192 WORD DRUM MEMORY EXPANDABLE TO 32768 WORDS.
4. PRIORITY INTERRUPT.
ANALOG INPUTS
300 SIGNALS ± 5 VOLTS
CLOCK INPUTS
1. E.S.T. 2. TIMER 3. COUNTDOWN
DISCRETE INPUTS
1008 ON-OFF SIGNALS 0 VOLTS OR 28 VOLTS
AIRBORNE COMPUTER
INPUT-OUTPUT REGISTERS
PAYLOAD G. S. E.
INPUT – OUTPUT REGISTERS
SIGNAL OUTPUTS
DIGITAL-ANALOG
DISCRETE OUTPUTS
1008 ON-OFF COMMANDS
REMOTE OPERATIONS
INPUT-OUTPUT REGISTERS
DIGITAL TELEMETRY
INPUT REGISTER
INPUT-OUTPUT
1. ELECTRIC TYPEWRITER ★
2. TAPE READER & PUNCH
★ Output Only
DISPLAYS
MAGNETIC TAPE EQUIPMENT

Figure 12.

address modifier registers. The speed of the machine, including access time, is 56 microseconds for addition, 728 microseconds for multiplication, and 868 microseconds for division.

The peripheral equipment in the present system has inputs for 300 analog voltages that are converted to 11-bit binary numbers with an accuracy of .1 percent. The computer complex can receive an analog signal, compare it with high and low rejection limits, and generate an alarm signal at the rate of 2200 such operations per second. This capability will allow a seemingly continuous check with all of these inputs to be interwoven to any of the various functions and duties of the computer complex on an almost non-interference basis.

The peripheral equipment also has inputs for 1008 discrete signals. These are on-off signals that can be scanned and compared to "should be" conditions retained in the computer memory at a rate exceeding 15,000 per second. The sequence in which these signals are scanned is determined by the computer program. The number of points can easily be increased, as is the case with the analog signals; only a change in the program and the addition of logic of the same type as is utilized in the present system is required.

The system outputs include 1008 discrete signals that can be individually controlled by the computer. These can be changed at any time to any configuration as directed by the computer program.

The system is also capable of generating an analog signal output. One 24-bit register is used to excite two D-A converters. These signals may be used as stimuli for components under test.

Another register is reserved for the telemetry-to-computer communication link. The computer can receive information from the digital telemetry system through this register.

Similar input-output registers ave available for clock inputs, for communication with the vehicle guidance computer, and for remote operations.

The magnetic and paper tape facilities and the typewriter serve at present as the input-output and recording media for the benefit of the human operator and for later evaluation. The magnetic tape may also serve as an addition to the bulk storage mentioned earlier.

The computer is able to retain all information in the event of a power failure. This is somewhat unique for a core machine and is accomplished by holding power up with capacitors long enough to store the contents of all dynamic registers in specific core locations. The program is then restarted from the point at which it was interrupted when power is returned.

Another interesting feature is the priority interrupt. The computer program may be broken into several sections, each one having an assigned priority level. Eight levels are available. If an external signal requests a priority level higher than the one being operated upon, the computer will sense this, store operands being used, and start operation of the higher level program in about 100 microseconds. When the priority signal is removed, operation is resumed on the next lowest level requested. In this way the computer may be made to operate on the program most important at any given time. As an example, the self-check routine could be assigned the lowest priority level and would then run at any time the computer is not carrying out its checkout activities.

Figure 13 describes a distributor system for remote displays or recorders which will be served by the operational computer. The acronym, REFEREE, has been chosen for the system. REFEREE stands for "Request from External Recording and Evaluating Equipment."

The REFEREE system distributes computer outputs to displays and recording equipment in accordance with established priorities. While "talking" with the priority interrupt system, REFEREE monitors the availability of data, receives requests for data from test conductors and other sources, and routinely furnishes data for master displays and for certain control functions. It protects the computer from inadvertent interruptions and vital operations.

At this writing, MSFC has one prototype display system on order. After experience with that system is gained during FY63, investigations into development of suitable display systems will be increased markedly. Only by using adequate display systems can the ideal man-machine combinations for automated launch control operations be determined.

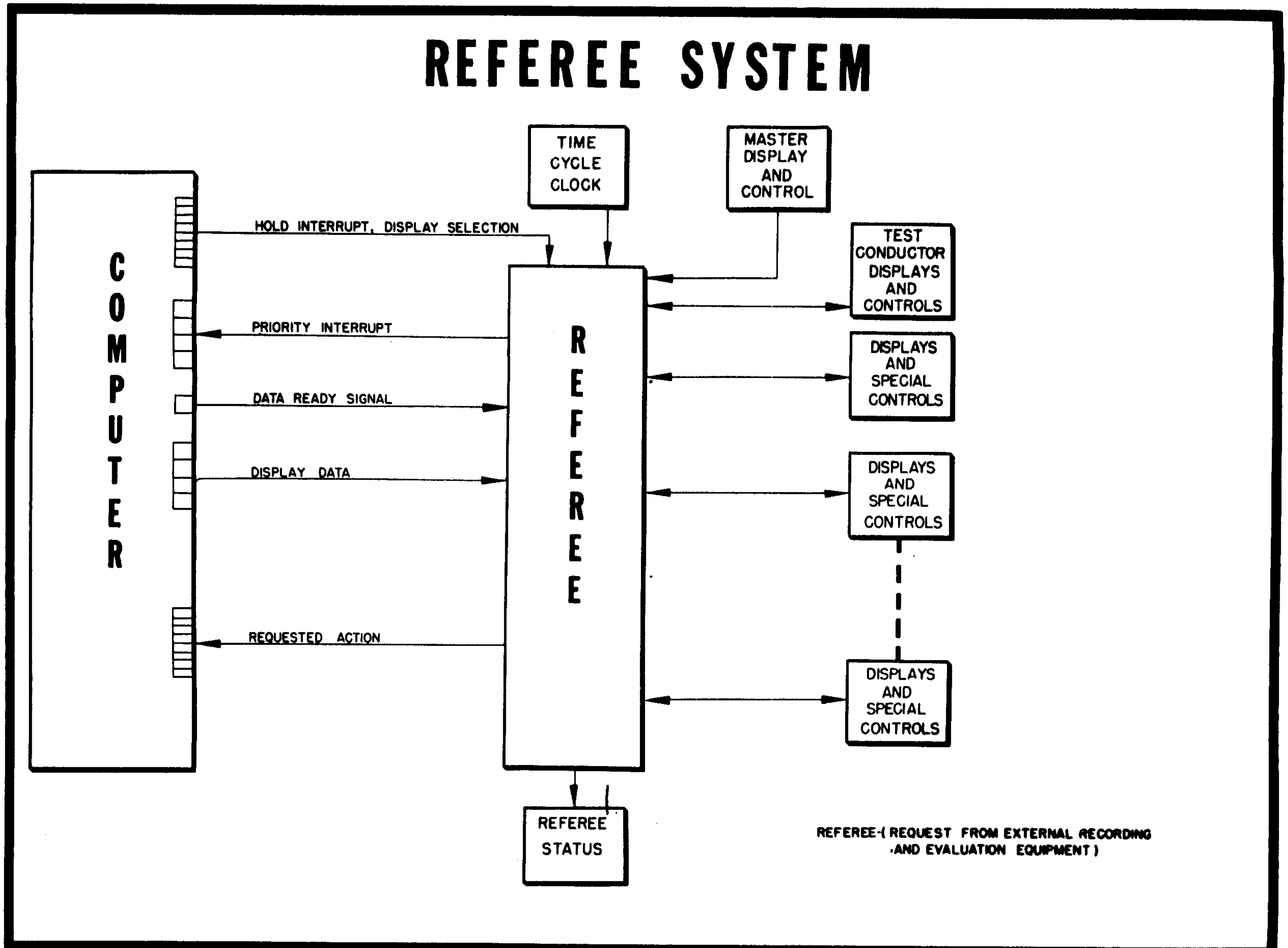

REFEREE SYSTEM
TIME CYCLE CLOCK
MASTER DISPLAY AND CONTROL
TEST CONDUCTOR DISPLAYS AND CONTROLS
DISPLAYS AND SPECIAL CONTROLS
DISPLAYS AND SPECIAL CONTROLS
DISPLAYS AND SPECIAL CONTROLS
COMPUTER
REFEREE
HOLD INTERRUPT, DISPLAY SELECTION
PRIORITY INTERRUPT
DATA READY SIGNAL
DISPLAY DATA
REQUESTED ACTION
REFEREE STATUS
REFEREE-(REQUEST FROM EXTERNAL RECORDING
AND EVALUATION EQUIPMENT)

Figure 13.

c. Complex 34 and Complex 37

The general block diagram for Complex 34 and Complex 37 is shown in Figure 14. The launching pad is approximately 1700 feet from the blockhouse, which serves as a launch control center. The vehicle at the pad area is tied through umbilical connections to a distribution system which carries the great bulk of systems circuitry to the blockhouse where information is displayed on recorders and consoles. On the consoles are controls that allow manual operation of the total vehicle system. Remote fueling facilities are provided on the pad and are controlled from the fueling panels in the blockhouse area. Measuring stimulation circuitry is provided in the pad to assist in performing whatever calibration may be required.

By approximately March 1963, the blockhouse for Complex 37 will have an operational computer complex which will be tied in a parallel fashion to the conventional launch-site circuitry. Signal conditioning, such as may be required for amplification of weak signals and for standardizing ac and dc voltages, will be performed on signals that require such treatment prior to transmission to the blockhouse in analog form. Within the blockhouse, the computer complex will monitor all operations and, at the discretion of the test conductor, will perform some or all of the operations required for checkout and launch of the vehicle.

In this fashion, personnel of Launch Operations Center will become familiar with the vehicle system operation through manual operation of the consoles and through observation of recorders that, in effect, duplicate the operations which will be handled by the computer complex in the automatic mode. The manual operation capability of the system serves as a back-up for the eventual automatic mode and will be used until reliability and operator confidence are such that an automatic system can be used for checkout and launch.

d. C5 Automation

Figure 15 shows a typical layout for the C5 operations plan as conceived by LOC. In this plan, the upper stages, including the spacecraft, are first brought to the stage checkout area and are qualified as individual stages (the booster may or may not pass through a stage checkout site). The stages are then assembled into vehicles in a vertical fashion on transporters in the high bay or vertical assembly

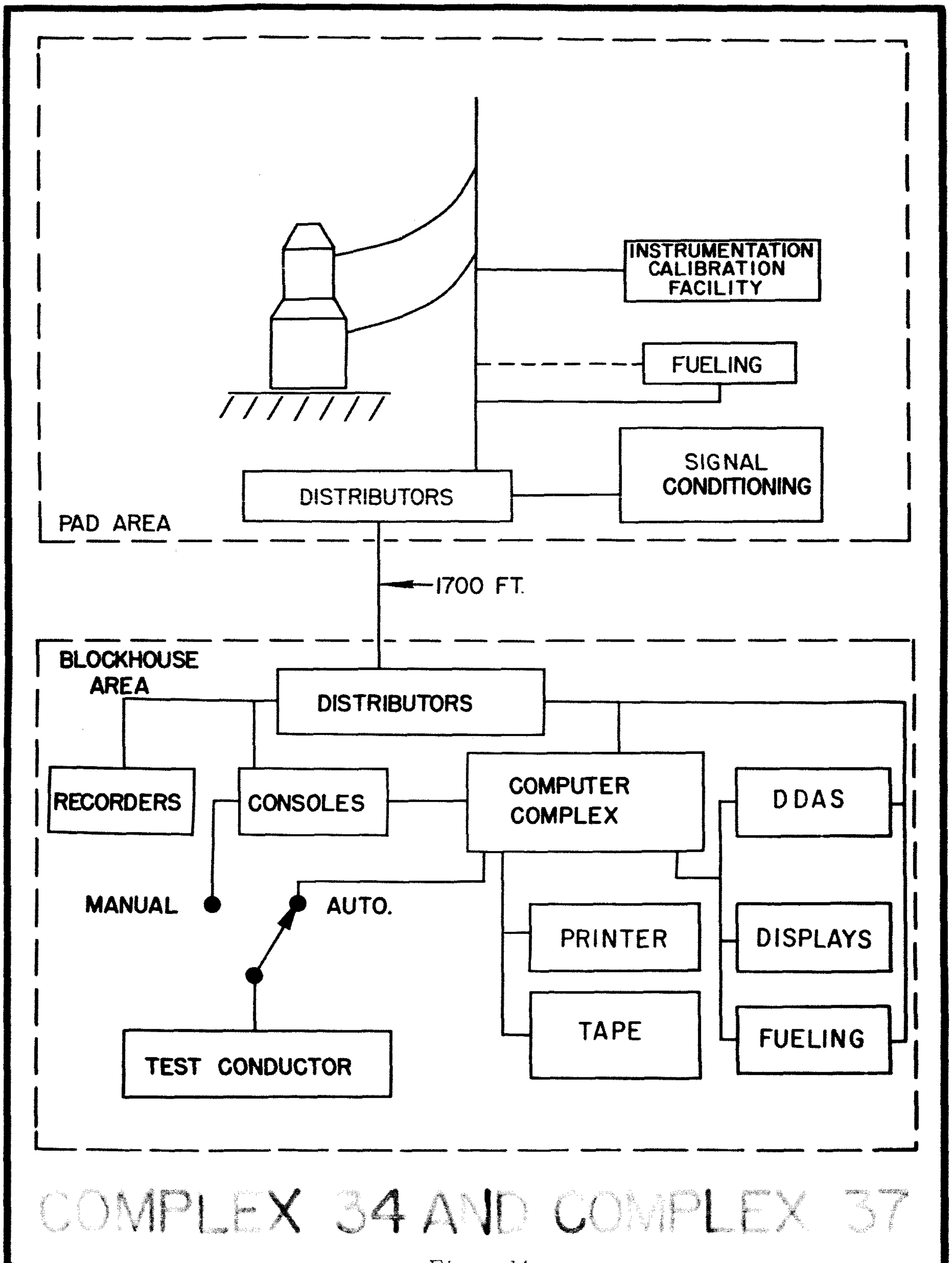

INSTRUMENTATION CALIBRATION FACILITY
FUELING
SIGNAL CONDITIONING
DISTRIBUTORS
PAD AREA
1700 FT.
BLOCKHOUSE AREA
DISTRIBUTORS
RECORDERS
CONSOLES
COMPUTER COMPLEX
DDAS
MANUAL
AUTO.
PRINTER
DISPLAYS
TAPE
FUELING
TEST CONDUCTOR
COMPLEX 34 AND COMPLEX 37

Figure 14.

C-5 OPERATIONS PLAN

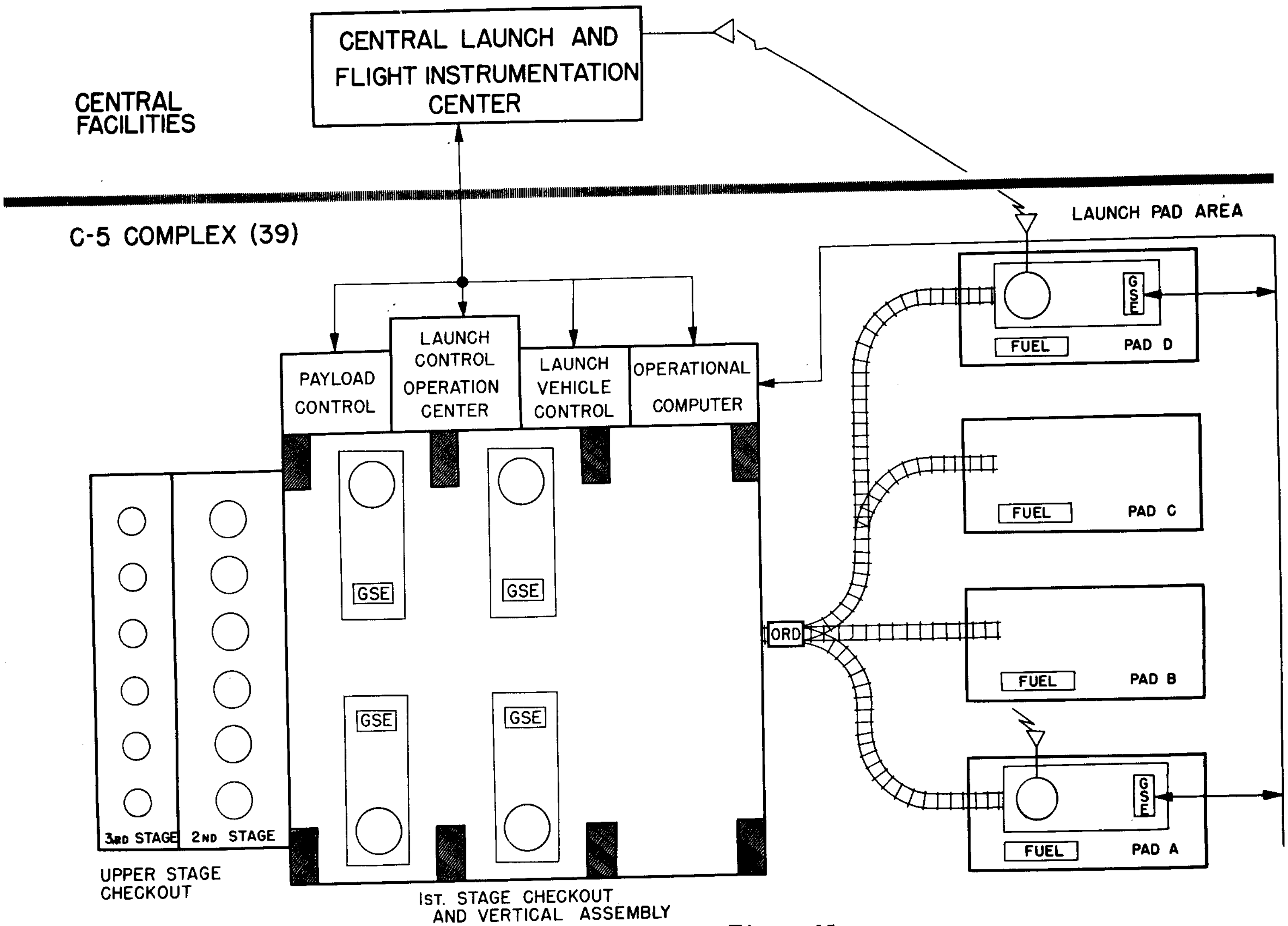


Figure 15.

area. Each transporter has its own set of GSE and is capable of complete and independent operational checkout of the vehicle system. During this time, measuring and telemetry checkout can be accomplished in conjunction with the Central Launch and Flight Instrumentation Center.

At a time which will probably be no greater than one week before launch, a transporter with its checked-out vehicle and GSE system will be moved along the rail system to take its firing position on pad A or pad B. Along the way it will receive ordnance item installation, high pressure checks, etc.

At the pad the vehicle system will be connected to fueling facilities similar to those used in the remote fueling operation of Complex 37. Checkout of the vehicle system can continue just as it did in the Vertical Assembly Facility since the transporter and its GSE are capable of independent operation. The Central Launch and Flight Instrumentation Center can continue to monitor all measuring adapter outputs through the RF link or over a closed coaxial connection. The pads will contain required power and air-conditioning facilities.

At a time when the entire launch operation is to be simulated, such as simulated flight test, the GSE will be tied through a communications link to an operational computer located at the Vertical Assembly Facility. All operations of the vehicle system will be transferred to Launch Vehicle Control, which will also be in the Vertical Assembly Facility. Vehicle system information can be sent to the Launch Control Operation Center and exchanged with the Central Launch and Flight Instrumentation Center. A command to the vehicle systems can be received from Launch Control Operations or Launch Vehicle Control and transmitted via the communications link back to the GSE on the transporter, which in turn causes the command to be carried out. On launch day, the system would operate in the same manner with the Central Launch and Flight Instrumentation Center being used for monitoring and controlling the vehicle after liftoff.

To elaborate upon the development plan for automation of the C5 vehicle, a description of Complex 39, as shown in Figure 16, is required. The transporters shown contain the measuring equipment, circuitry, and hardware necessary for remote fueling operations when they reach the launch pads. The electrical distribution system and the signal conditioning system serve the same purposes as those for Complex 37.

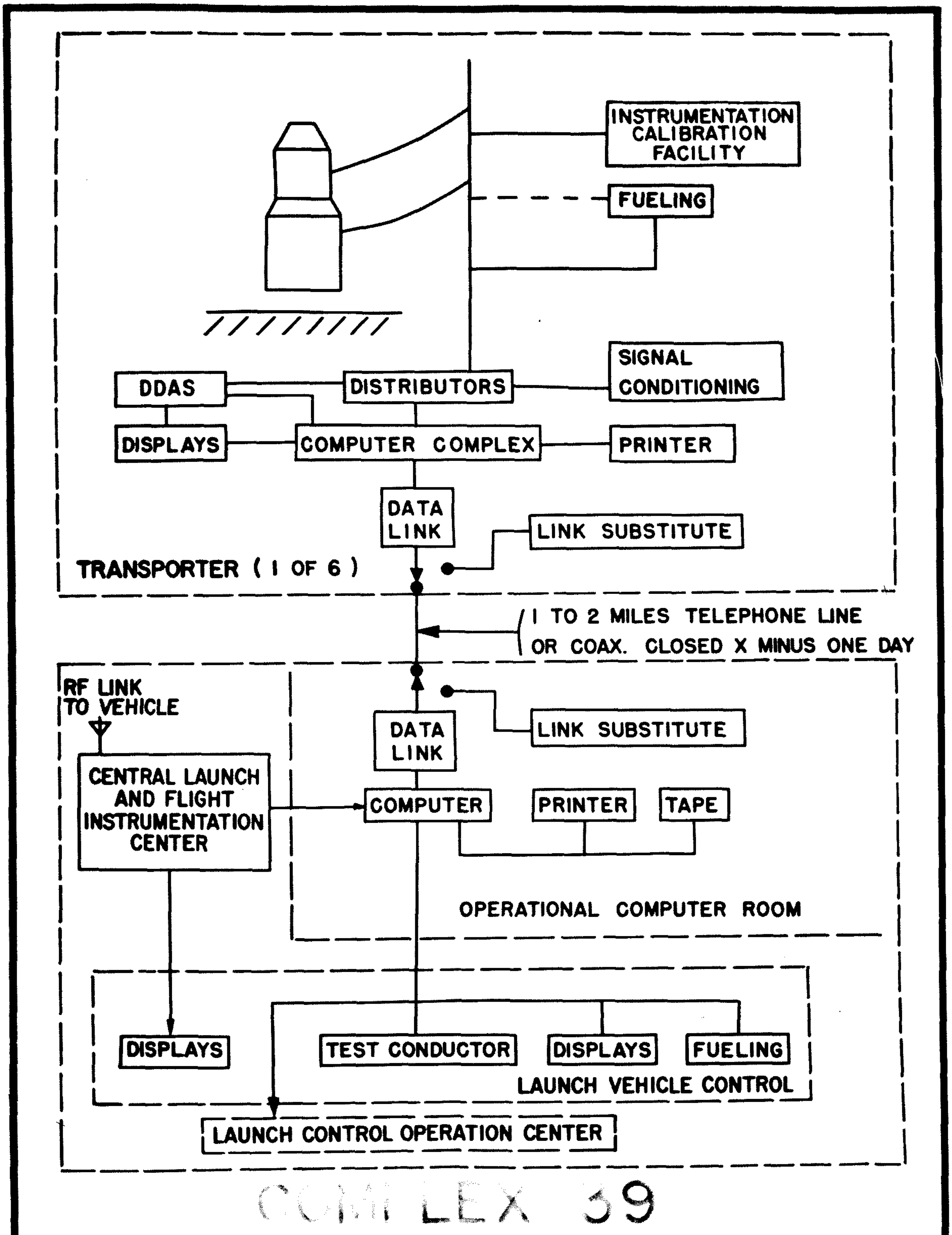

INSTRUMENTATION CALIBRATION FACILITY
FUELING
SIGNAL CONDITIONING
DDAS
DISTRIBUTORS
DISPLAYS
COMPUTER COMPLEX
PRINTER
DATA LINK
LINK SUBSTITUTE
TRANSPORTER (1 OF 6)
1 TO 2 MILES TELEPHONE LINE OR COAX. CLOSED X MINUS ONE DAY
RF LINK TO VEHICLE
DATA LINK
LINK SUBSTITUTE
CENTRAL LAUNCH AND FLIGHT INSTRUMENTATION CENTER
COMPUTER
PRINTER
TAPE
OPERATIONAL COMPUTER ROOM
DISPLAYS
TEST CONDUCTOR
DISPLAYS
FUELING
LAUNCH VEHICLE CONTROL
LAUNCH CONTROL OPERATION CENTER
COMPLEX 39

Figure 16.

The computer complex, with its displays and printer, permits a complete checkout of the vehicle operational systems while other preparations for vehicle launch are being made. The various transporters and their GSE systems can function independently of each other and of other checkout equipment and systems. The independence greatly enhances the capability and flexibility.

Remote operation is accomplished by closing a data link between the vehicle computer complex and the operational computer. In this mode the two computers operate effectively as one with the computer complex receiving commands from and transmitting results to the operational computer. The operational computer, in turn, operates displays and receives commands from the test conductor. To assure that the entire working system will be operative at the time of remote operation, a link substitute is provided on both ends of the data link. Normal checkout procedures, prior to remote operation, utilize the link substitutes to generate signals which are transmitted via the data link. These signals operate the computer complex and operational computer in the exact manner as vehicle inputs. Thus, at the time of remote operation, all hardware, except the conductor between the pad and the operational computer, has been qualified.

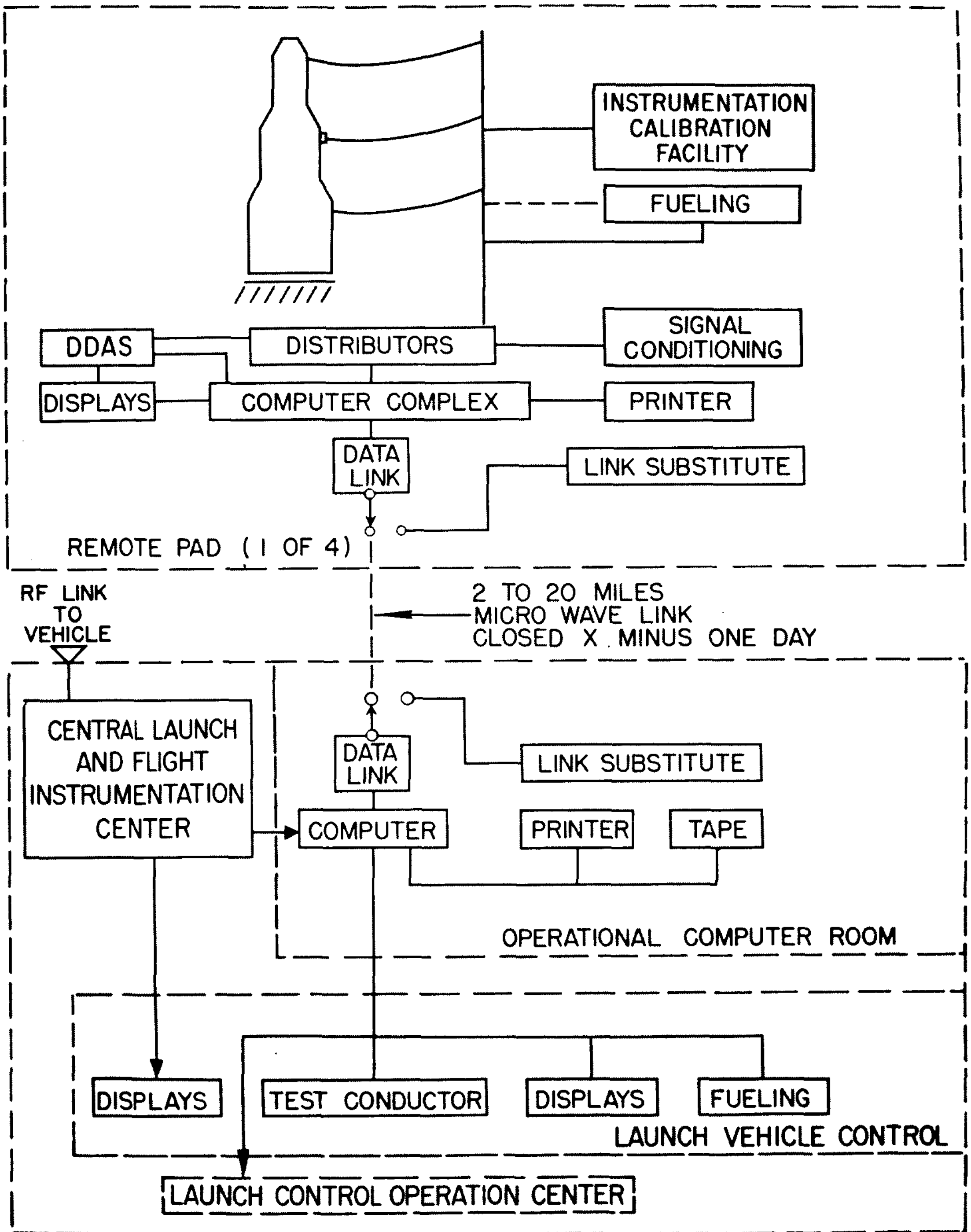
Hardware and technologies developed in the operation of Complex 37 can be directly applied to the C5 operations plan. When the C5 system goes into operation, the only hardware that would be new to Launch Operations Center personnel should be the vehicle itself.

e. Nova Automation

In launching vehicles larger than the Saturn C5, the transporter concept will probably not be used. In this case, the vehicle could be assembled directly on the launch site, and there may be as many as four of these installations. A central facility will still probably contain an operational computer room and a launch vehicle control room. Figure 17 shows the remote application for Nova firings. The only real difference between this configuration and that required for C5 will be the distance covered by the data link. Here again, independent operation capabilities for each launch site will be necessary.

3. Automatic Checkout Systems Development Facility

During the early discussions which led to the formulation of MSFC's concept for automated launch control operations, it became



REMOTE APPLICATION

Figure 17.

apparent that an R&D facility would be needed to develop the required systems and techniques and to prove their adequacy for launch operations. Consequently, it was decided to locate an automatic checkout "breadboard" facility at the Astrionics Division, MSFC, to duplicate launch-site equipment and operating condition to the maximum extent feasible.

Figure 18 depicts the automatic checkout facility being constructed for the C1 vehicle. It will initially contain the electrical support equipment (ESE) for the S-1 stage, an operational computer, digital data acquisition equipment, and an instrument unit electrically identical to that of SA-5. The S-1 stage will be electrically simulated utilizing flight-type distributors, sequencers, and other electrical flight hardware. The entire vehicle can be electrically simulated with the aid of stage interface substitutes.

In the beginning, mechanical systems will not be "breadboarded." However, a feasibility study is underway to determine the best method for "breadboarding" mechanical systems later in the C1 program.

The primary objectives of the Automatic Checkout Systems Development Facility are:

a. To provide a facility where MSFC design sections may carry out system design development and evaluation of both the vehicle and electrical automatic support equipment (EASE).

b. To provide a means of checking the response of vehicle and EASE to induced malfunctions.

c. To conduct interference tests.

d. To develop proven test methods, procedures, and displays.

e. To provide a basis for maintainability analysis.

f. To provide personnel familiarization and training.

g. To provide a facility at which changes and modifications to the vehicle and EASE may be evaluated.

h. To design and evaluate the detailed computer programs required for the checkout and launch site operations.

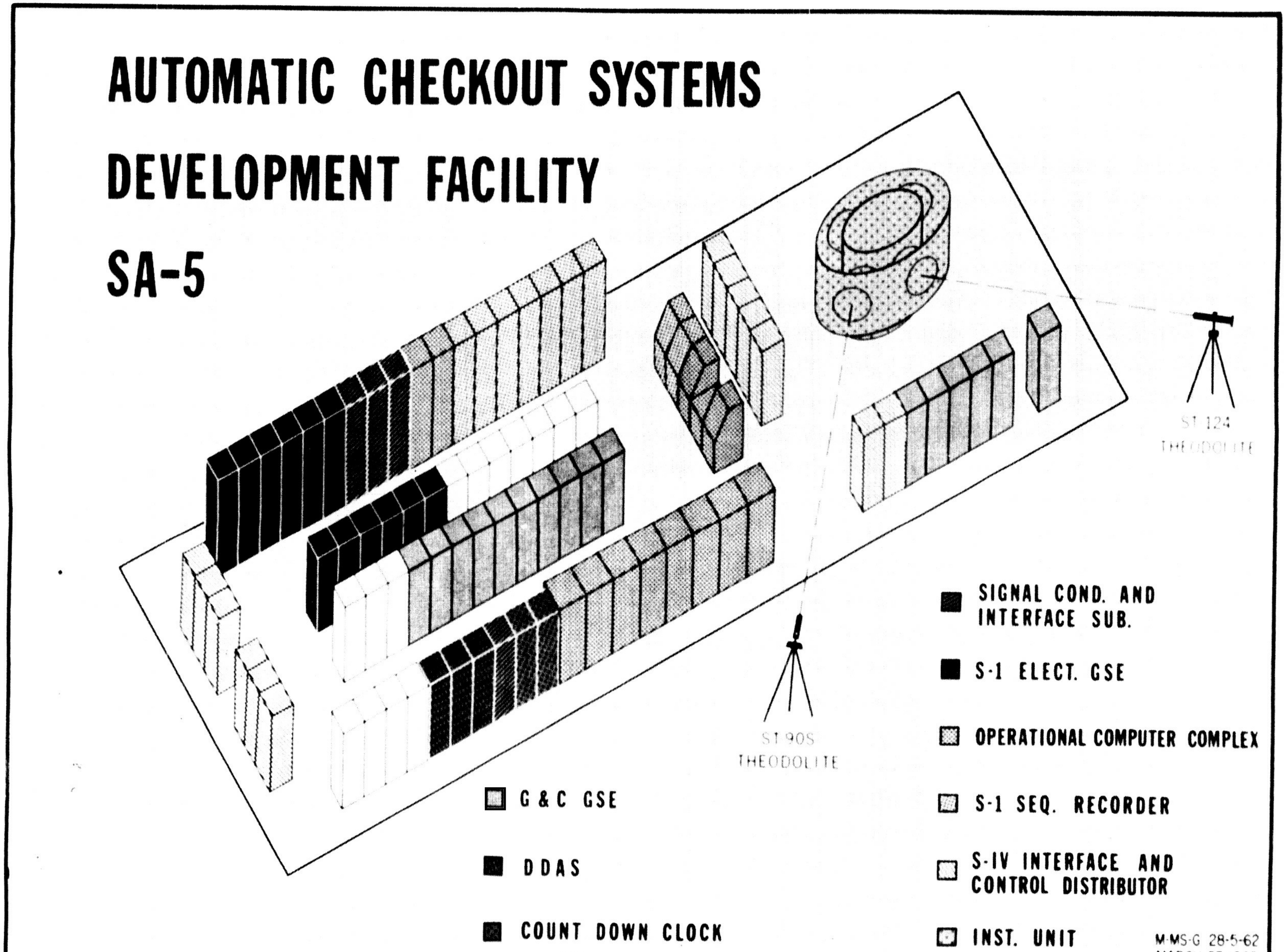

AUTOMATIC CHECKOUT SYSTEMS
DEVELOPMENT FACILITY
SA-5
ST 124
THEODOLITE
ST 90S
THEODOLITE
G & C GSE
DDAS
COUNT DOWN CLOCK
SIGNAL COND. AND INTERFACE SUB.
S-1 ELECT. GSE
OPERATIONAL COMPUTER COMPLEX
S-1 SEQ. RECORDER
S-IV INTERFACE AND CONTROL DISTRIBUTOR
INST. UNIT
M-MS-G 28-5-62
MARCH 23, 1962

Figure 18.

Present schedules call for the start of checkouts of C1 Block II, S-I stage electrical support equipment with the S-I stage electrical simulator in this facility in August 1962. The prototype instrument unit and its electrical support equipment are scheduled for delivery to the facility in September.

The C5 automatic checkout systems development facility is presently only in the planning stage. It is intended that it will accomplish the same overall objectives as the C1 facility. It is planned that a prototype instrument unit and the S-IC "All Systems" vehicle be utilized in this facility for systems verification.

C. DATA ACQUISITION FOR VEHICLE MONITORING AND CHECKOUT

Availability of accurate, current data on vehicle status is essential to the successful operation of an automatic vehicle monitoring and checkout system. The method frequently proposed for this requirement includes hard wire connections from each data point to a ground sampling and digitizing system. In the complex Saturn vehicle system, this approach presents a number of difficult system problems:

a. The number of connections which must be routed through the stage umbilicals is impractically high.

b. Electrical ground loops, noise pickup, connector contact resistances and potentials, line capacitance, and other problems are inherent in analog transmission over hard wires.

c. Measurements of the vehicle telemetry system are carefully calibrated for standard input and output impedance relationships; therefore, the addition to these points of parallel impedances that are removed at liftoff is not practical. This presents a severe problem because a considerable number of the data points required for checkout are also telemetered.

d. Accurate data sampling is very difficult to achieve when a long line, representing considerable capacitance, separates the transducer and the multiplexer switch.

These problems and others associated with use of hard wires for data transmission led to the consideration of the vehicle telemetry system as a source of data for vehicle prelaunch monitoring and checkout.

1. Saturn Telemetry System

The telemetry problem presented by the Saturn vehicle is much more difficult than that presented by previous missiles and launch vehicles. The size and complexity of the vehicle require an unusually large quantity of measurements. The variety of data categories that must be monitored presents diverse requirements upon the telemetry system. The tremendous cost of individual vehicles demands thorough instrumentation to obtain the maximum practical amount of data from each vehicle. Likewise, it is imperative that reliability and performance be the best that state of the art allows.

The telemetry approach utilized in the Saturn vehicle evolved from experience with the Redstone, Jupiter, and Pershing programs, which were completed without significant losses of telemetry data. An appropriate combination of three basic telemetry techniques are used in the Saturn to provide the required transmission capacity and characteristics. These systems are PAM/FM/FM, SS/FM, and PCM/FM. Each of these systems has characteristics appropriate for specific categories of data; in combination, they form an efficient, reliable, flexible data gathering system. Figures 19 and 20 show the SS/FM and the PAM/FM/FM telemetry system.

2. Adaptation of the Saturn Telemetry System to Prelaunch Vehicle Monitoring

In considering the adaptation of the Saturn telemetry system to prelaunch vehicle monitoring, the following questions were carefully analyzed:

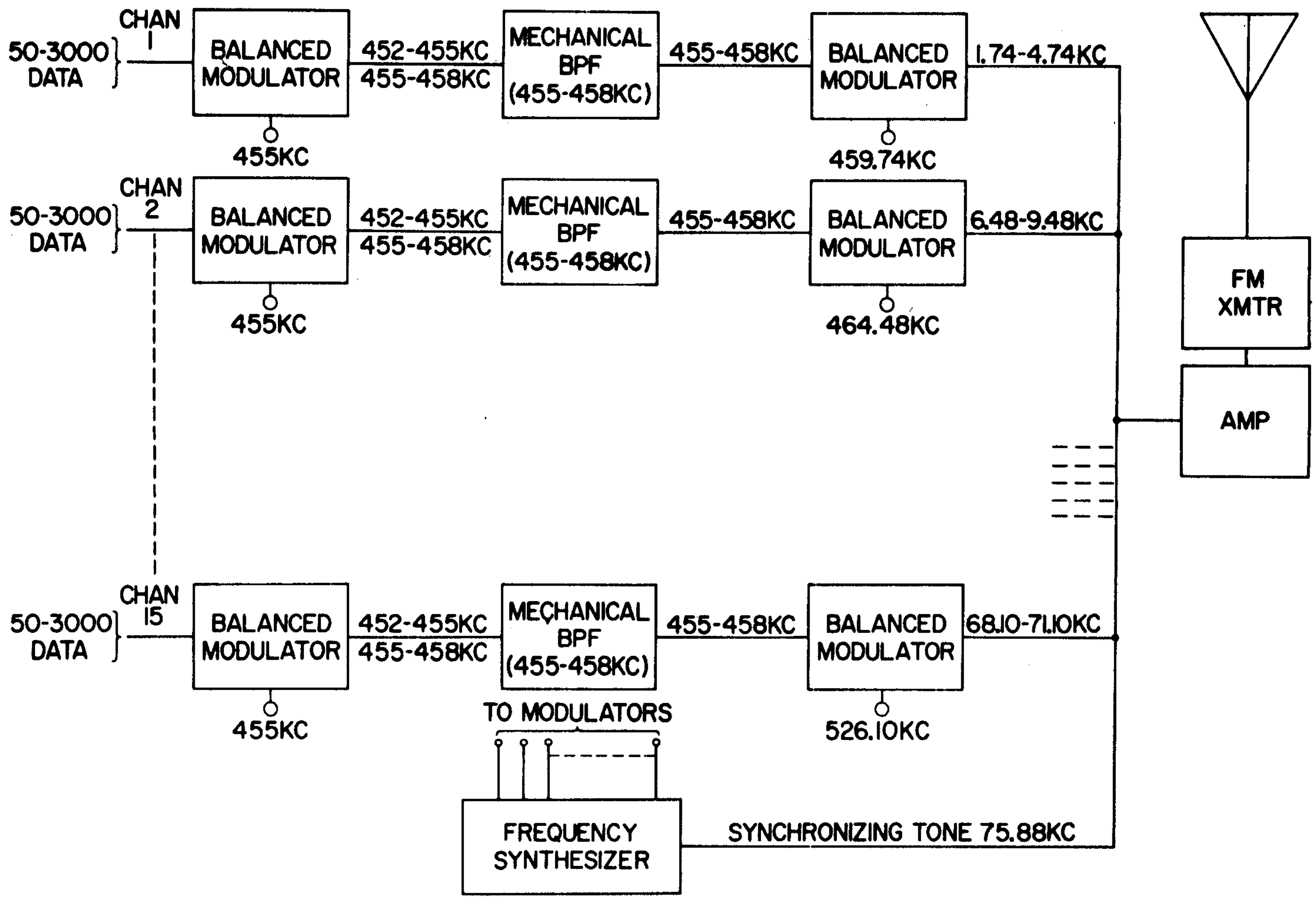
a. Could the existing telemetry system be readily modified to provide an output in a form suitable for real time computer entry?

b. Could the telemetry system be adapted to prelaunch data use without decreasing its capability for flight telemetering?

c. Could telemetry equipment planned for Saturn serve as a utility link during many hours of prelaunch testing without deteriorating its capability after liftoff?

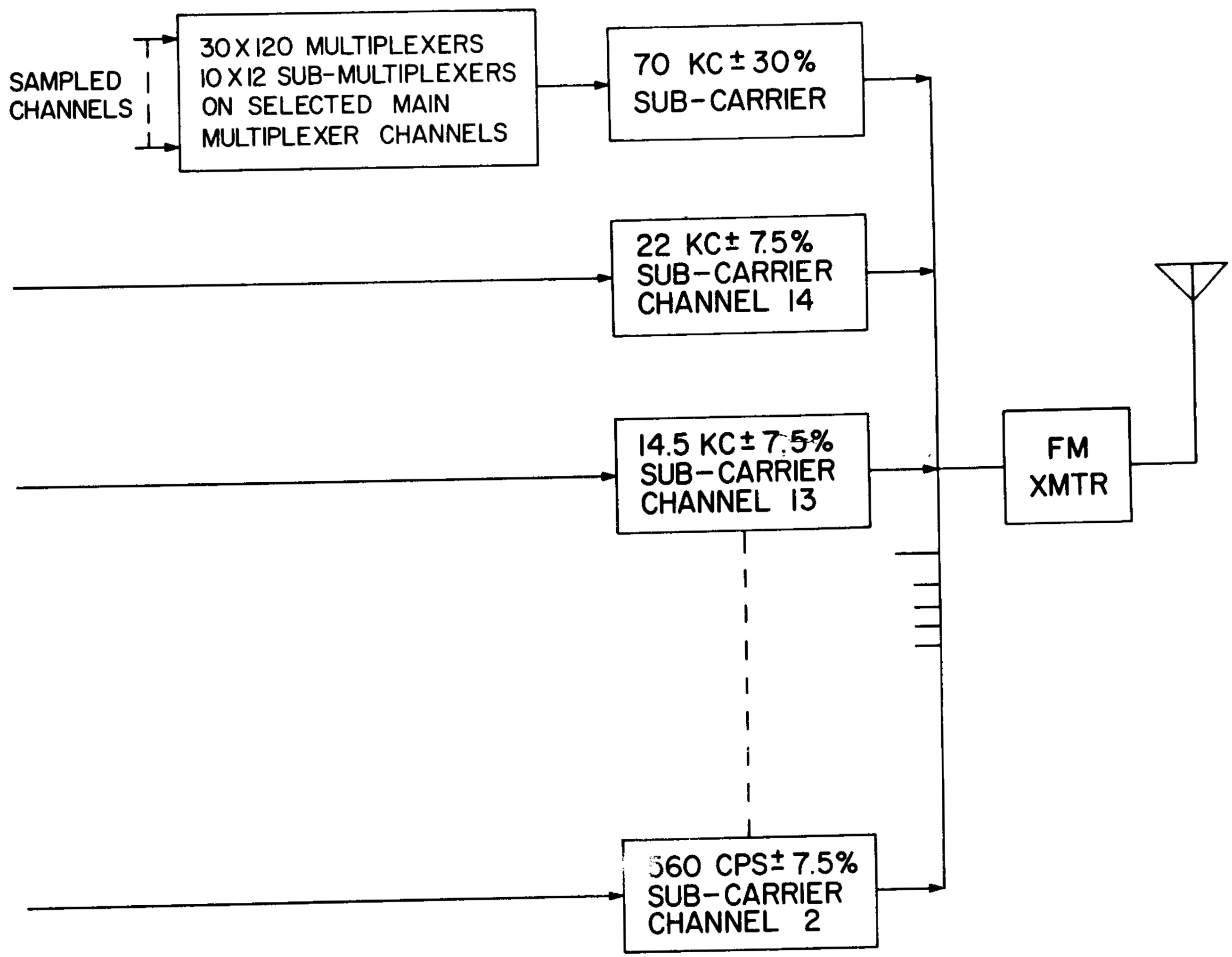
d. Could the resulting data acquisition system provide self-checking features?

e. Could the resulting system provide means for checking the instrumentation and telemetry as well as other vehicle systems?



SS-FM TELEMETRY SYSTEM FOR VIBRATION AND OTHER WIDE-BAND DATA.

Figure 19.



SATURN PAM-FM-FM TELEMETRY SYSTEM

Figure 20.

Each of these questions was carefully considered and design modifications of the vehicle telemetry system were evolved which provided an affirmative answer to each of these questions.

The essential features of the vehicle telemetry adaptation for prelaunch monitoring are as follows:

a. Analog measurements required for vehicle readiness determination and also for inflight telemetry must be presented to their multiplexer of subcarrier channel with no special connections required.

b. Analog measurements required for vehicle readiness determination, but not normally telemetered in flight, must be connected to existing multiplexer channels and sampled at rates appropriate to the expected prelaunch dynamic character of the measurement.

c. All subcarrier measurements must be parallel connected to multiplexer channels and sampled at rates appropriate to the prelaunch dynamic characteristics of the measurement (most of these are static during prelaunch).

d. The high-capacity multiplexer developed for Saturn must be utilized to perform the multiplexing specified in b. and c. above. This multiplexer has been modified to add features required for the ground digital data acquisition subsystem application. The capability of accepting external synchronization and an additional data wavetrain output were the essential modifications. These multiplexers have basic channel sampling rates of 120 samples per second and 12 samples per second. With the addition of the programed scanning discussed below, channel sampling rates of 120, 40, 12, and 4 samples per second are available over the digital data acquisition subsystem (referred to as DDAS).

e. A vehicle telemetry subsystem must provide the following functions:

(1) Synchronization signals to all multiplexers.

(2) Electronic switches which scan the auxiliary data outputs of all multiplexers on the specific stage (this typically will vary from 2 to 6 on an R&D stage) and in a programed sequence connects each multiplexer output to the input of a 10-bit analog-to-digital converter.

(3) Formating and serializing logic which places the data in serial NRZ digital format.

(4) An FM carrier generator and modulator.

Scanning of multiplexers is programed so that only each third frame is accepted from certain multiplexers, thus reducing the channel sampling rate of these channels in the DDAS output to 40 and 4 samples per second. At least one multiplexer in each stage will be digitized and its output provided to the ground DDAS without reduced sampling rate. This provides channels with sampling rates up to 120 per second for specific measurements with dynamic characteristics.

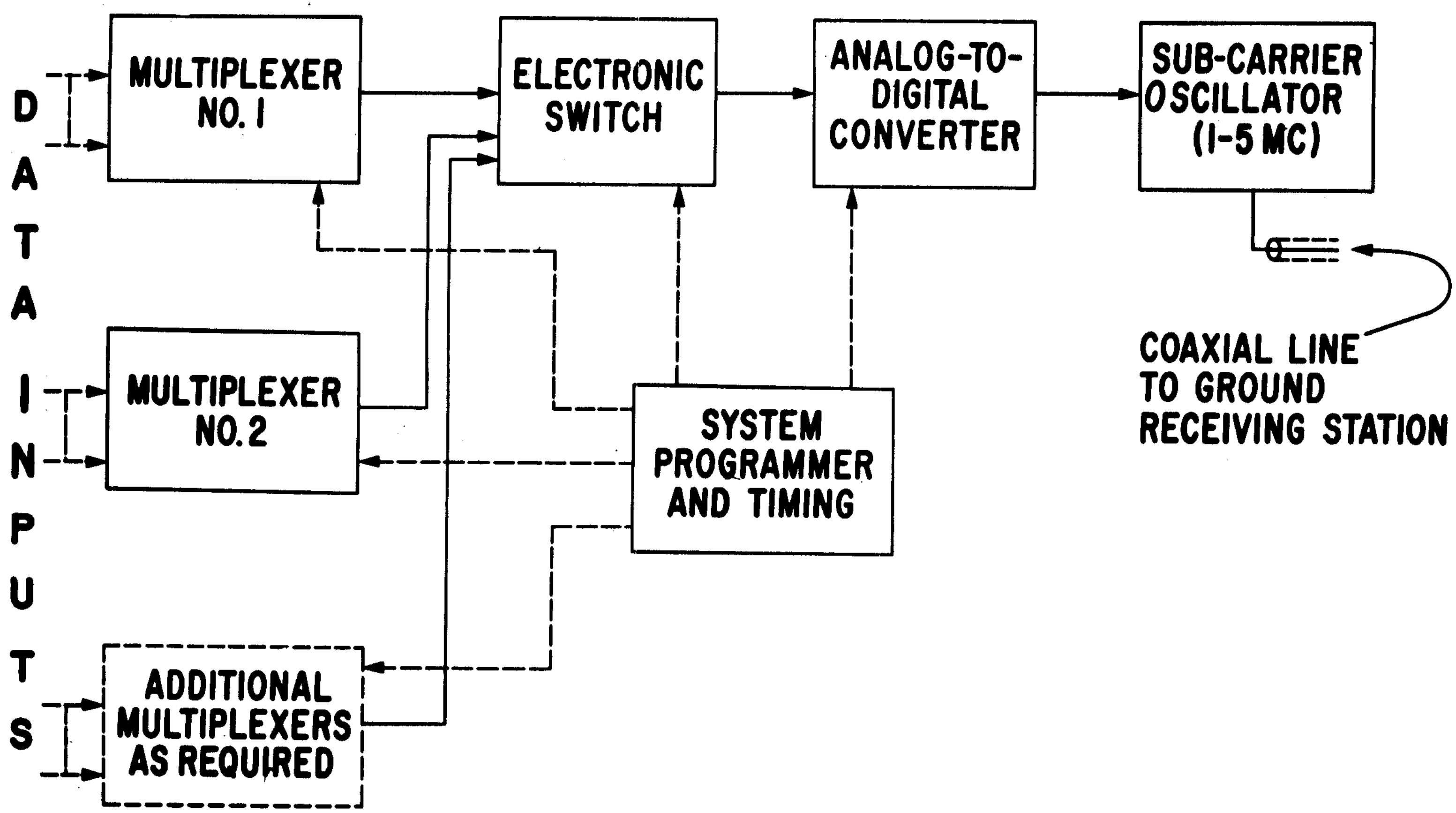
The general characteristics of the DDAS format from each stage telemetry system is as follows:

Word rate	- 7200/second
Bits/word	- 10
Bits/second	- 72,000
Words/frame	- 60
Frames/subframe	- 30
Frame identification	- 20 bits/frame
Subframe identification	- Frame is complemented each 30 frames.

No word resynchronization, parity bit, or word separation bits are utilized. Two reference channels from each multiplexer are digitized and transmitted through the system as a continuous check on DDAS operation.

Primary power is applied separately to those portions of the vehicle telemetry that are not used for prelaunch monitoring through the DDAS output (subcarrier, RF transmitter, RF power amplifiers, etc.). The DDAS may then serve as a utility link at any time data is required from the stage, including stage preparation and checkout (Figure 21).

The non-return-to-zero modulated FM carrier is routed by coaxial line through the stage umbilical. The DDAS carriers from the separate stages are staggered in frequency from 0.5 to 1.5 megacycles and may be transmitted from the vehicle to the computer locations by a common coaxial cable. For distances in excess of 5 miles, it is expected that a microwave link will be used.



VEHICLE PCM DATA ACQUISITION SYSTEM FOR AUTOMATIC CHECKOUT

Figure 21.

An optional capability of the system is providing the DDAS output over an RF carrier from the vehicle stage in addition to the coaxial (or microwave) link. This will permit real time vehicle monitoring after liftoff by an operational flight control system.

The RF link would also provide a degree of redundancy in the inflight telemetry transmission, as well as a means of accurately calibrating the instrumentation system in flight. Figure 22 shows a typical stage telemetry system modified for the DDAS capability.

3. Ground Digital Data Acquisition Subsystem (DDAS)

A digital data receiving subsystem provides the following functions at each location where data from the system is utilized.

a. Selection of data source (i.e., stage 1, stage 2, etc.). This selection may be made manually or on command from the computer.

b. Demodulation, bit-rate clock reconstruction, and regeneration of the serial digital data.

c. Demultiplexing, buffer storage, and presentation in parallel digital form of any specific data channel on command from the computer.

d. Demultiplexing and presentation of selected channels in analog and digital form to visual displays and analog recorders.

e. Magnetic tape storage of data for future reference.

The basic operation of the ground DDAS is shown in Figure 23. A receiver and demodulator unit accepts the selected incoming data carrier from the coaxial or microwave link. The output of the unit is the digital NRZ wavetrain corrupted to a certain degree by noise generated during the transmission process. The wavetrain is restored to the original noise-free form (the form in which it was applied to the carrier modulator) by the data reconstruction unit. The unit also extracts the bit rate of the incoming wave and produces a clock signal for the remainder of the system. The correlator and serial-to-parallel converter unit contains two digital filters that recognize the two series of binary digits which have been assigned as frame and subframe identification. It also provides the registers required for serial-to-parallel conversion.

VEHICLE TELEMETRY SYSTEM

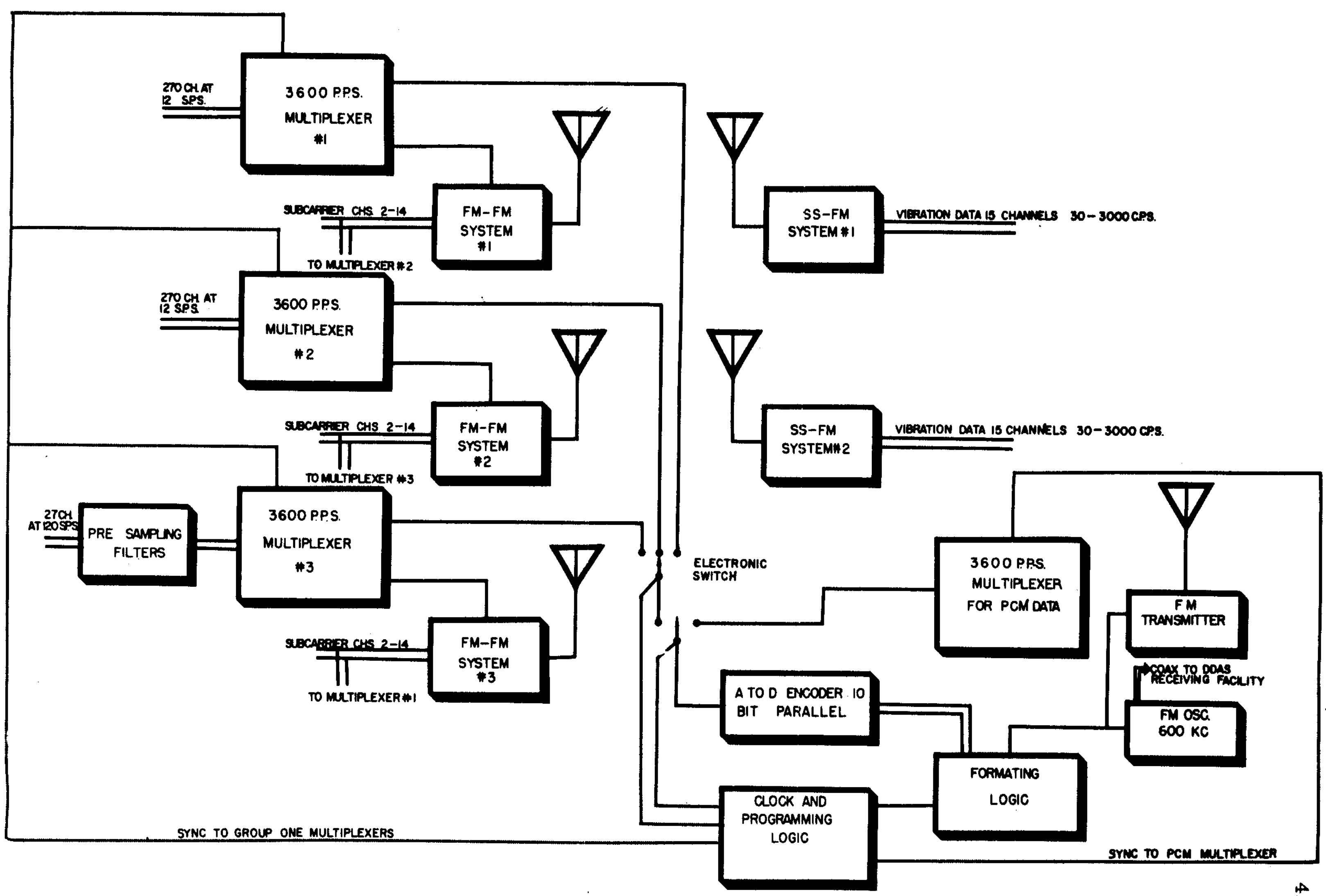
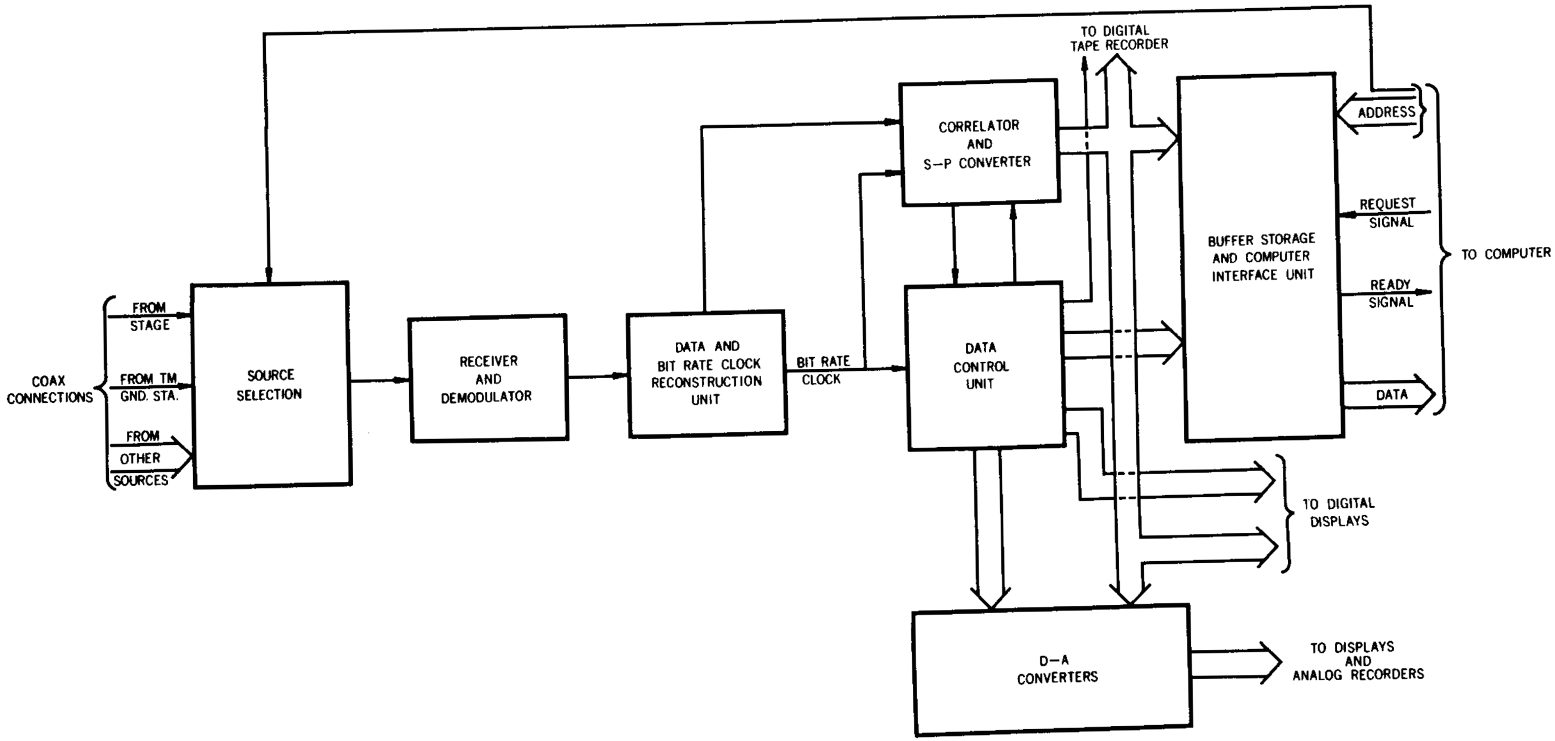


Figure 22.



GROUND DDAS
(STAGE CHECKOUT VERSION)

Figure 23.

The data control unit performs a number of functions. It examines frame and subframe sync indications from the correlator for periodicity. This is necessary to detect series of data bits that may occasionally resemble the sync identification code. It also contains the logic required to detect an out-of-sync condition and search logic for locating the correct frame sync code. The "true" frame sync indication resets a group of counters, which count in the same sequence as similar counters located in the vehicle telemetry systems. The state of the counters provides the "address" of the data channel that is currently in the S-P data register. A matrix and patching arrangement permits the selection of specific control pulses to be routed to other units. This includes channel selection pulses to the digital-to-analog converter (referred to as D-A converter) and the digital display units and also pulses that transfer selected data to buffer storage in the computer interface unit.

The digital-to-analog converters contain holding registers plus resistive networks required for digital-analog conversion. Each channel has outputs for driving a meter, a strip-chart recorder, and a high current output for oscillographic recording. These outputs are stairstep outputs, i.e., the analog value of the preceding sample is held until the next sample arrives. Each group of eight D-A converters is mounted in a three and three-fourth inch rack, together with a calibration and metering unit.

The buffer storage and computer interface unit provides the language media between two non-synchronous digital systems — the DDAS and the digital computer. The DDAS appears to the computer as a memory. The computer sends a request and specifies the desired data by setting an address register. The requested data is transferred to the data output register and a "ready" signal notifies the computer system that the data is ready for use (Figure 24).

The values of specific measurements are transferred to buffer (magnetic core) storage, providing the computer an access time of 5 to 10 microseconds on these channels. Computer access time to channels not transferred to buffer storage is dependent on channel sampling rate. For example, average access time on a 12 samples per second channel is 40 milliseconds; for a 120 samples per second channel, it is 4 milliseconds. A program patch board determines which measurements are transferred to buffer storage.

DDAS—COMPUTER INTERFACE

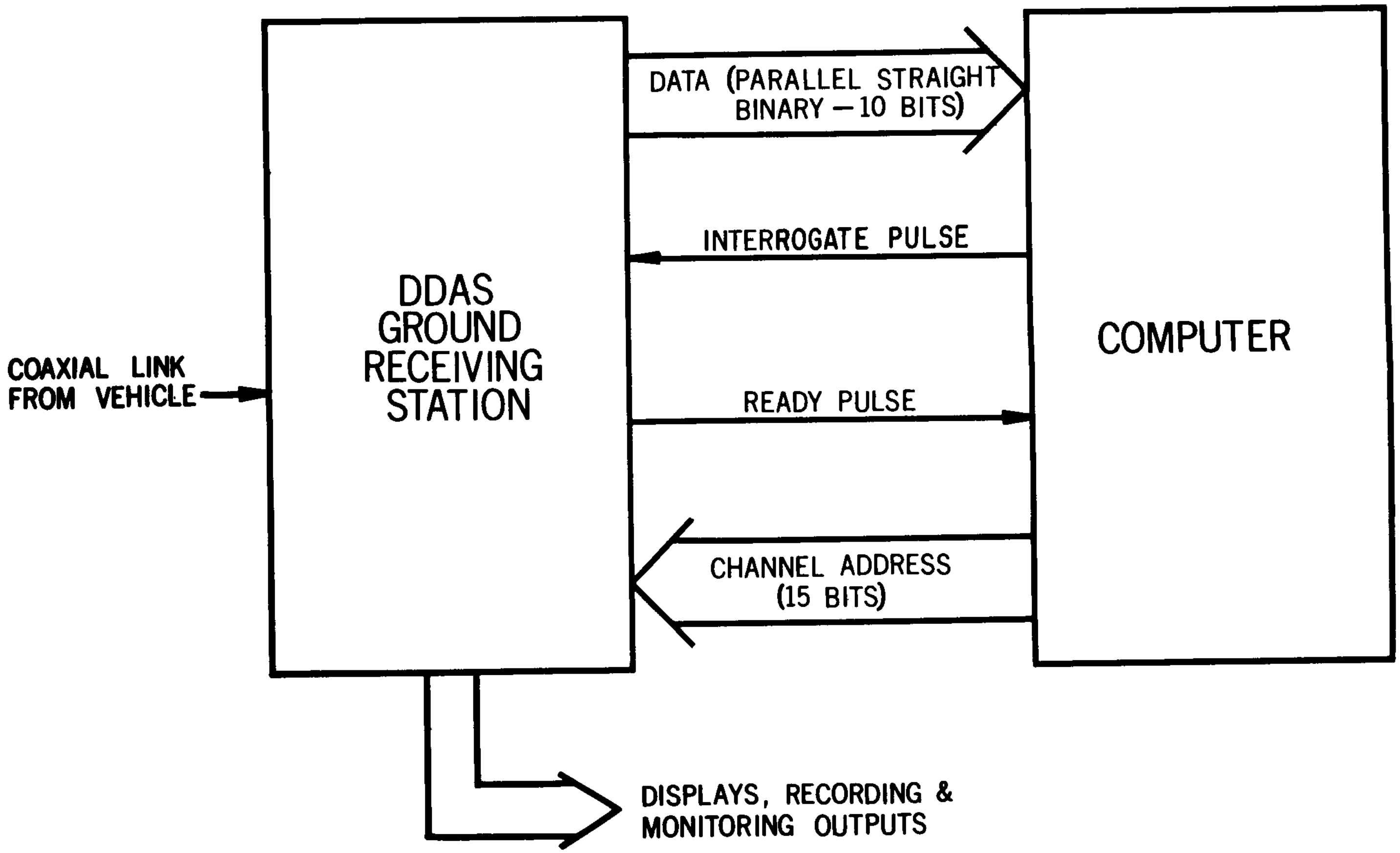


Figure 24.

The ground DDAS may be assembled in one of several arrangements to suit the particular installation requirements. Essentially, this version provides a one-channel demodulation and demultiplexing system with manual or computer controlled source selection preceding the demodulator. A number of channels may be presented in analog form for display or recording, depending upon the individual installation requirements.

A monitoring version of the ground DDAS is essentially identical to the stage checkout version except that the computer interface unit is not required. This version may be utilized at locations where only display and recording is required.

The launch-site version of the ground DDAS must provide to the checkout computer data channels from any vehicle stage with an access time that is compatible with critical prelaunch decisions. This requires that the demodulation and demultiplexing be performed in parallel channels which terminate in a common buffer storage and computer interface unit. Also, the buffer storage capacity that is required for the launch-site installation is considerably greater than other installation requirements. Refer to launch-site DDAS system in Figure 25.

The unitized design of the ground DDAS permits each of the several versions to be assembled from the same basic units. Also, this design philosophy facilitates future design improvements and modifications resulting from experience during the C1 program.

4. Application of the DDAS Concept to Future Saturn Problems

An important feature of the DDAS concept is its compatibility with orbital operations and operational flight control. In either case, the addition of an RF link for transmission of the vehicle DDAS output provides a ground-based computer complex with the data required for real time decisions. A digital command link, now under development for Saturn, provides the return link for computer instructions to the vehicle. In addition, a vehicle version of the ground DDAS system can provide a vehicle computer system with the data needed for its participation in orbital checkout and other orbital operations. Another possible application of the DDAS stage output is to provide the occupants of a manned spacecraft with the data for visual monitoring of the stage.

LAUNCH SITE DDAS SYSTEM

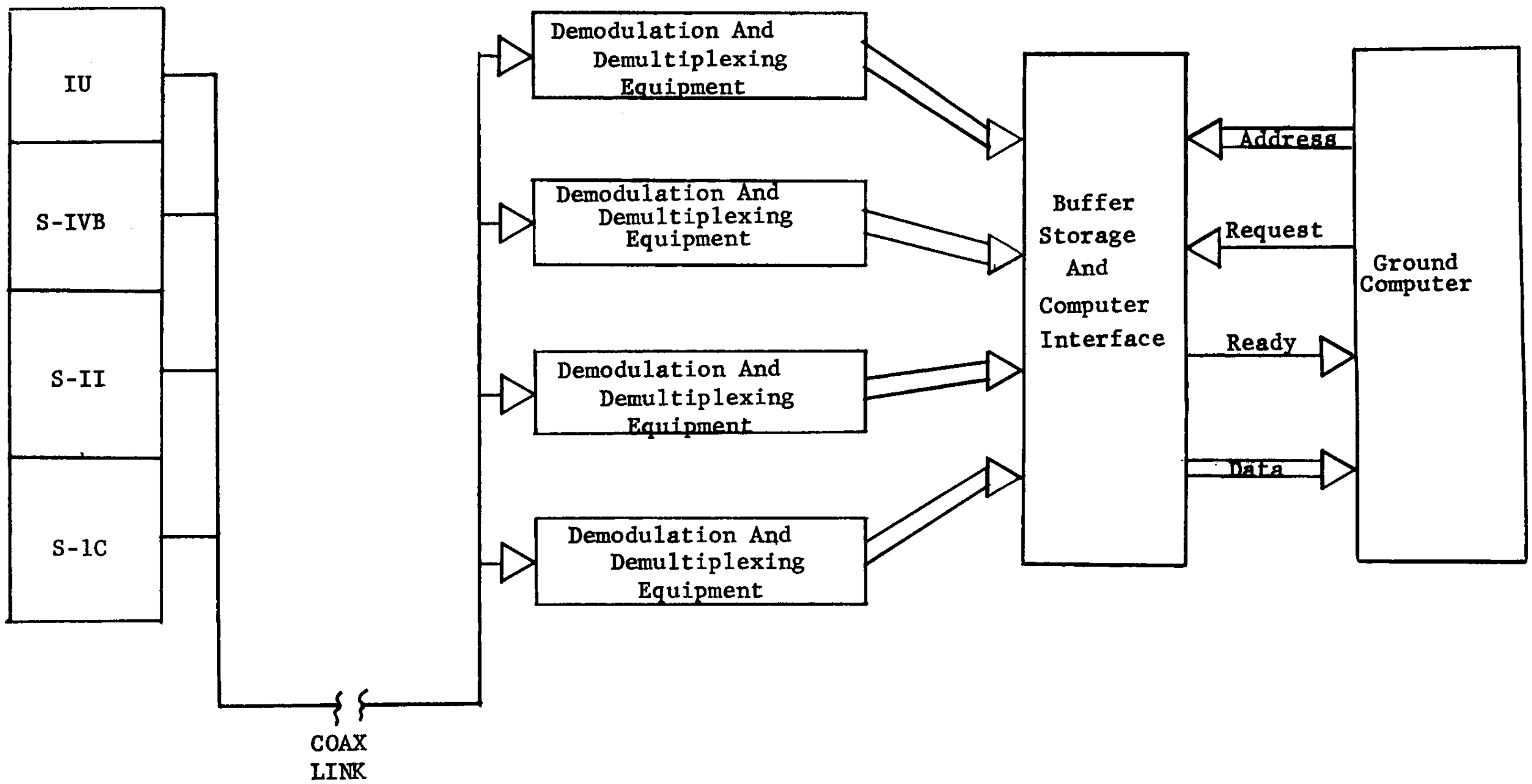


Figure 25.

5. DDAS Development Program

The features that enable the vehicle telemetry system to provide prelaunch data acquisition capability have been included as an essential characteristic of the telemetry system design for the Saturn Cl vehicle. The Saturn telemetry development is being accomplished by a group of competent contractors, under the systems cognizance of the Instrumentation Development Branch, Astrionics Division. Figure 26 shows the schedules for including telemetry equipment with DDAS output capability in the S-I stage and instrument unit of the Cl vehicle. Stage contractors for the C5 configuration are being directed to use telemetry design concepts providing the DDAS capability; therefore, all stages of the C5 configuration will have initially the DDAS output capability.

The development program for ground DDAS equipment for the Saturn Cl R&D program is shown in Figure 27. System one will be installed in the automation breadboard at Astrionics Division in August 1962. Systems two and three for Quality Assurance Division and LOC will follow in time for experimentation with automation techniques on SA-5. The schedule allows for design feedback for operation of the automation breadboard into the LOC DDAS.

6. Conclusions

Some improvements in the overall automatic vehicle monitoring and checkout system, which result from use of the data acquisition and transmission techniques, are described as follows.

Factors reflecting on reliability:

a. The number of wired connections between the vehicle and launch pad is minimized.

b. Problems from electrical ground loops, noise pick-up, connectors, cable losses, etc., that are inherent in analog data transmission over hard wires are reduced.

c. Data is changed into digital form as near the source as practical, resulting in minimum chance for errors in the system.

d. Digital telemetry techniques provide a more reliable error-free transmission medium than other techniques, including analog transmission over separate hard wires.

Schedule for Incorporating Telemetry Vehicle Equipment with

DDAS Capability In The SATURN C-1 Program

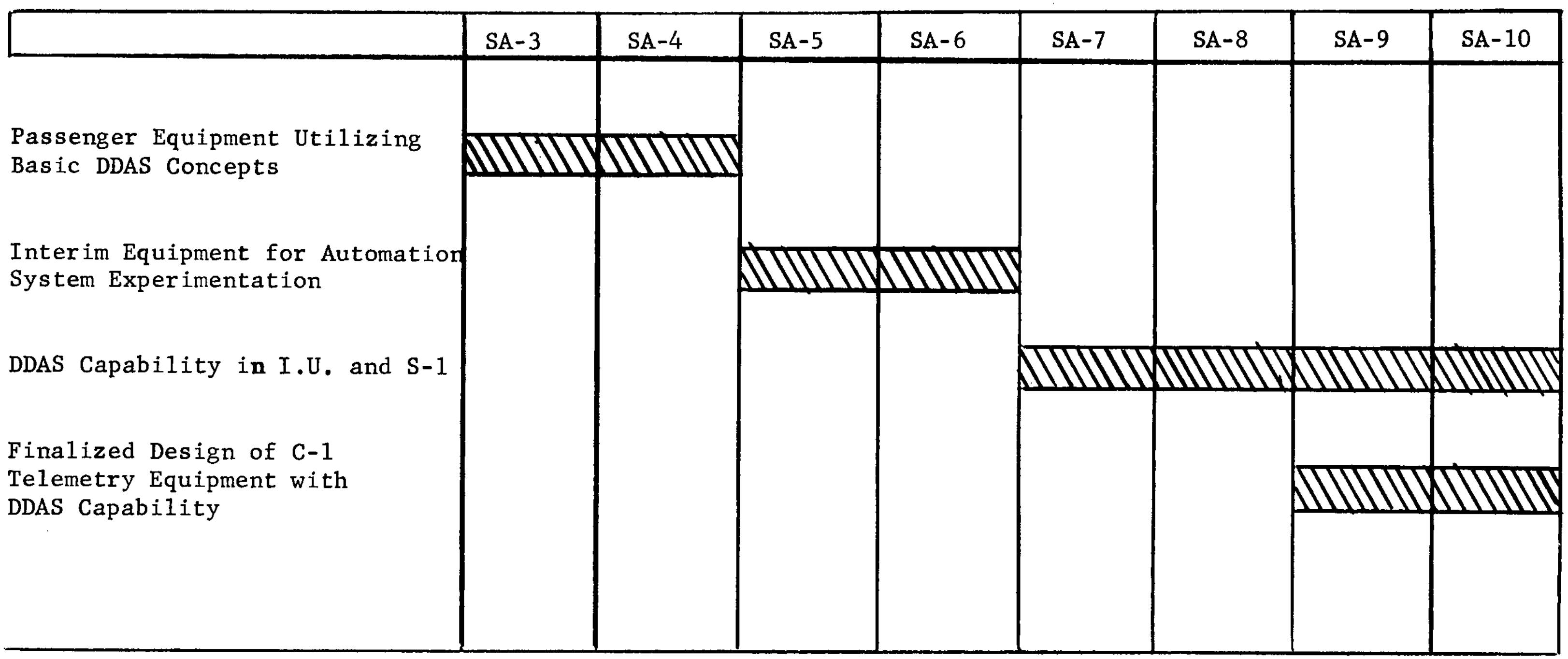


Figure 26.

DDAS GROUND SYSTEM DEVELOPMENT SCHEDULE

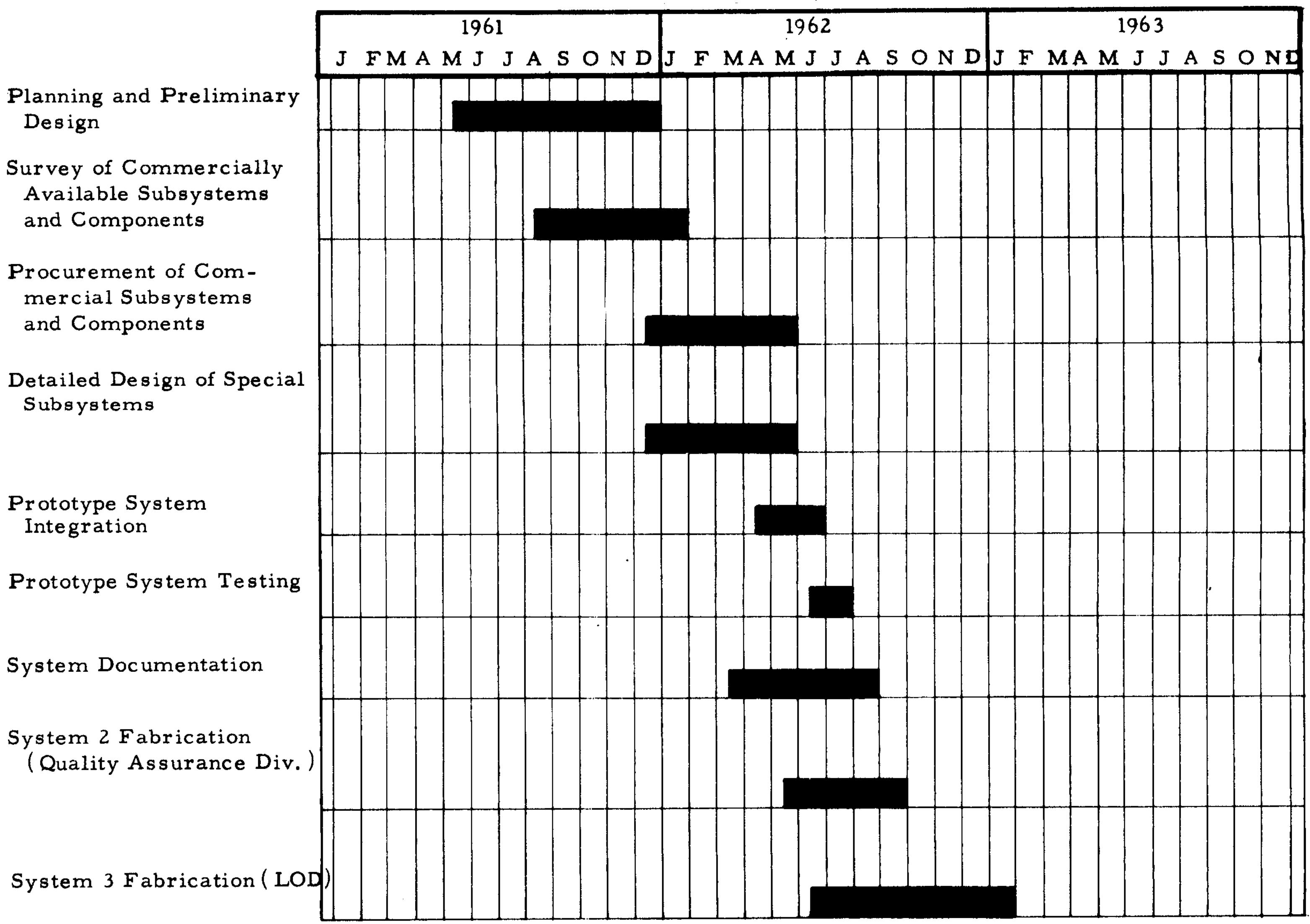


Figure 27.

Factors reflecting on flexibility:

a. Data can be presented to several computers at separate locations, if it is desirable to involve more than one computer in the checkout procedure. This only necessitates an additional ground DDAS installation adjacent to each computer location and additional data links to the vehicle location.

b. The technique permits automatic vehicle monitoring and checkout with a minimum of change in the vehicle system as it exists for non-automatic procedures.

c. The concept facilitates a gradual change-over to automatic techniques (any measurement made available to the computer in digital form can be available as an analog output for visual monitoring and display).

d. Distance between vehicle and computer is not a basic limitation on system feasibility.

e. Monitoring may be continued after liftoff with no modification of basic system concept.

f. The resulting system is compatible with future, more sophisticated techniques such as closed-loop operation after liftoff using the command system as the return link to the vehicle.

g. The resulting system expands naturally into a future system in which real time monitoring during orbital launch operations is required.

h. The resulting data acquisition and transmission system mates readily with any available computer. The only change required to mate with a different computer is minor modification of the ground DDAS computer interface unit.

D. STAGE AND INSTRUMENT UNIT CHECKOUT OPERATIONS

The basic checkout philosophy for individual stages is essentially the same as for the launch vehicles themselves. Automated methods must be used in the interest of reliability and time savings.

In many cases, the same automated test procedure will be used for stage checkouts as will be used later at the launch site. In the case of the C5 vehicle, stage checkouts using very similar, if not identical, checkout equipment will be carried out at the manufacturing sites, at captive test sites, and at the stage checkout area of Complex 39. By standardizing test and checkout procedures and equipment and by utilizing standard data retrieval and processing methods, excellent records of component, systems, and stage performances under test will be readily available for comparison or evaluation at the launch site.

As was pointed out earlier, a major difference between launch pad operations and stage checkout operations lies in the proportions of measuring stimulation and calibration operations carried out at the two types of installations. A much larger portion of the test and checkout activities at stage checkout areas will relate to proving instrumentation systems.

Checkout of a vehicle's instrument unit, whether C1 or C5, will follow the same concepts as for individual stages. At present, such operations are MSFC responsibilities.

This section will concern only the checkout operations associated with prestatic test and poststatic test. At a later date, detailed concepts for static test site automation will be released.

The primary purpose of stage tests and checkouts is to obtain reliability and readiness-for-launching data. Accordingly, much attention will be given to component testing at the manufacturing site, although the primary emphasis will be placed on systems' performances during checkouts.

1. Saturn C1 Checkout

As has been pointed out, MSFC is responsible at present for checking out both the S-1 stages and the C1 instrument units prior to their shipment to Cape Canaveral. Accordingly, the C1 operations depicted herein relate primarily to the operations of the Quality Assurance Division; however, Michoud operations will be virtually the same.

It was determined at an early date that the Quality Assurance Division checkout facilities should include a number of stations to serve as satellites to the central computer complex. Each of the widely-separated remote stations is assigned a specific test or checkout mission. The following discussion offers details on the operations performed by the satellite stations and shows how they are controlled by the central computer.

2. Instrument Unit Checkout

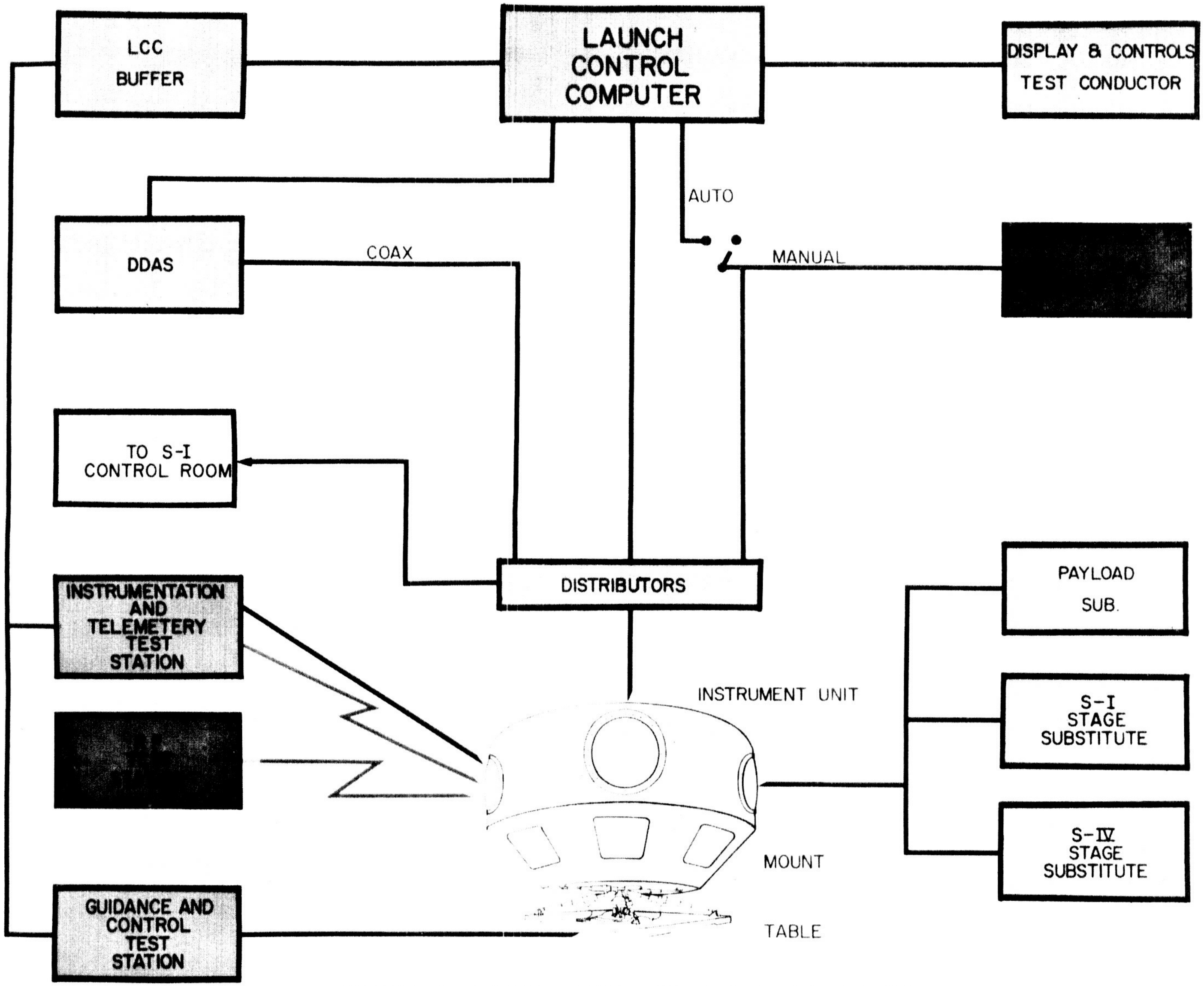
The instrument unit contains the elements necessary to properly perform guidance, instrumentation, measuring, and telemetry. Associated with the test and checkout of the instrument unit are five satellite stations. These are the guidance and control test station, the instrument and telemetry test station, the RF test station, the instrument unit test station, and the instrument unit control center. It is the purpose of these stations to test flight components such as the guidance computer, control computer, stabilized platform, horizon sensors, program devices, gyros, angle-of-attack meters, telemetry, instrumentation, power elements, cooling, and other elements. The tests are first performed component-wise and then mated to provide system integration tests. In most instances, it is necessary to perform tests on the instrument unit without the other vehicle stages. This requires that stage interface substitute units be incorporated in the test to ensure that proper interface arrangements have been made.

The instrument unit test operation is shown in Figure 28. Each satellite station has the capability of operating in the automatic or manual mode; however, in either case, the test program is controlled by the launch control computer. For example, if an operator should send a request to the computer asking it to perform the required test, the launch control computer would control the test as determined by a specific program. As the test is performed, the computer is gathering data and transmitting it back, in real time, to the station for printout of the test results.

The instrument unit control center contained in the instrument unit test operations is unique. It has the capability of controlling certain portions of the instrument unit checkout manually. This control center contains a general purpose computer (launch control computer) that is programed to produce discrete outputs, signal stimuli, and input commands to the flight guidance computer. These signals are used to produce input commands to the instrument unit components whose outputs are fed to the various satellite stations for component evaluation.

3. Booster Checkout

The S-I booster contains the engines, fuel tanks, actuators, and other hardware required to perform first stage operation. The test and checkout configuration of the S-I stage is shown in Figure 29. This



INSTRUMENT UNIT TEST

Figure 28.

C-1 SATURN CHECKOUT

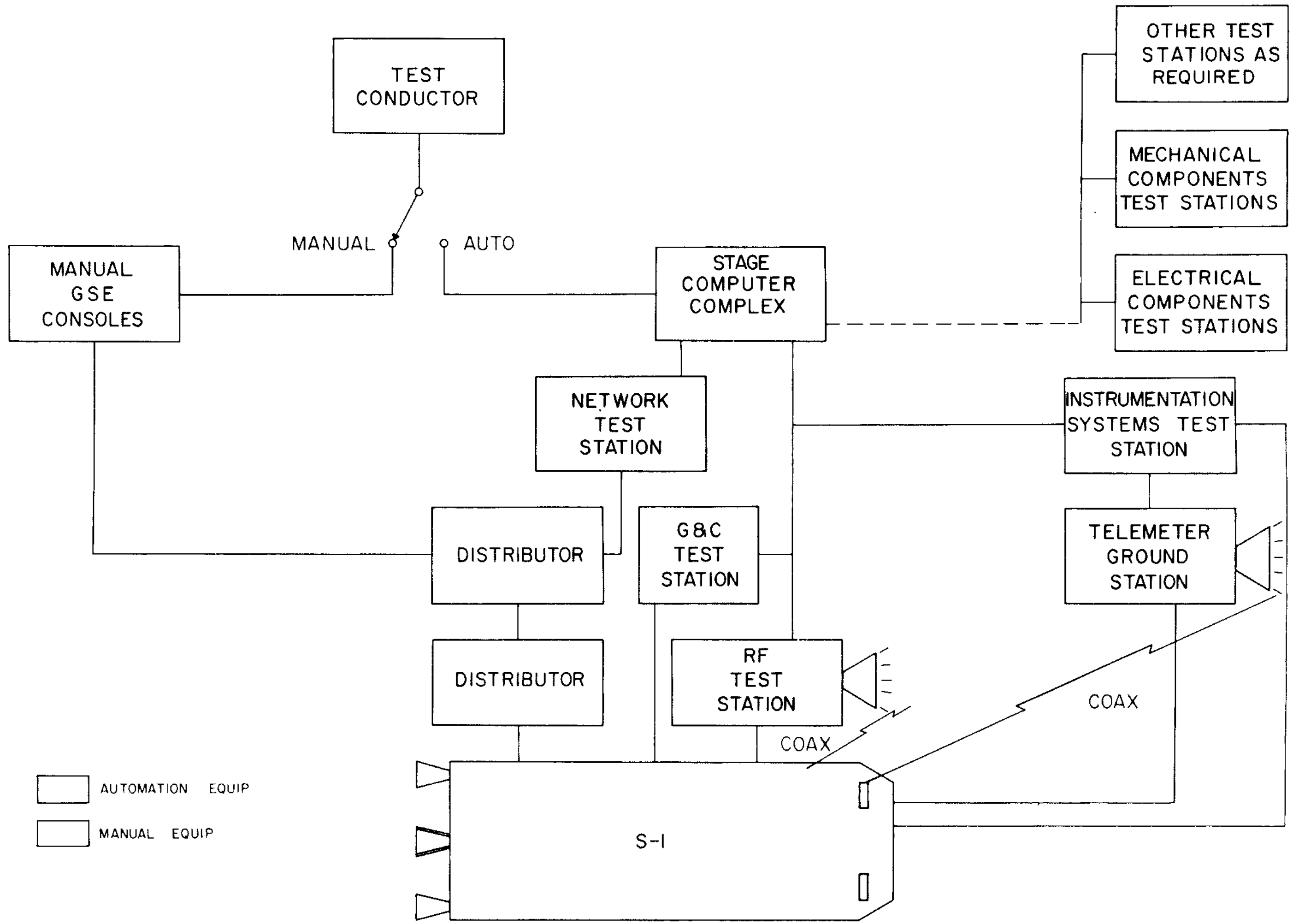


Figure 29.

diagram indicates that some of the satellite stations used in the instrument unit checkout are also required for S-I checkout. In this test, interfaces for the other stages are also tested.

The purpose of the check is to ensure that the valves, relays, actuators, flight sequence, cutoff, and other electrical and mechanical operations are performing properly.

4. Present Status of Automated Equipment

The first group of automated test equipment for checkout of the S-I stage is presently in production at the Packard Bell Computer Corporation. The first scheduled application of this equipment is the checkout of the S-I stage of Saturn vehicle SA-5 at MSFC during 1962. Certain satellite stations, with some additional equipment, will also be used for checkout of the Saturn instrument units at MSFC. One stage computer complex, with satellite test stations, will be government-furnished to check out the S-I stages produced at the Michoud plant.

5. Instrumentation Systems Checkout

Design for the Saturn interim instrumentation and telemetry automatic checkout station was completed in April 1961. The contract for the checkout equipment was awarded to the Packard Bell Computer Corporation in May 1961. The interim checkout station was received in August 1961, and preliminary checks on SA-2 during prestatic and poststatic checkout were attempted; however, because of the limited time allocated for checkout, the results obtained from these tests were incomplete and not conclusive.

The checkout station is a computer-controlled automatic checkout system for use on portions of the instrumentation and telemetry systems (Figure 30). By means of an internally stored program, control words provided by the computer to the system control logic determine the stimulus to be applied to the transducers. After the stimuli has been applied, the analog-to-digital converter converts the response output signals. The results of conversion of the response signals are then entered into the computer, compared to stored calibration curve values, and computations are made to determine go no-go signals. All data or "no-go" data can be printed out and the data and decisions can be stored for off-line study. A typical printout of data for off-line study is shown in Figure 31.

INTERIM AUTOMATED CHECKOUT BLOCK DIAGRAM SA 3

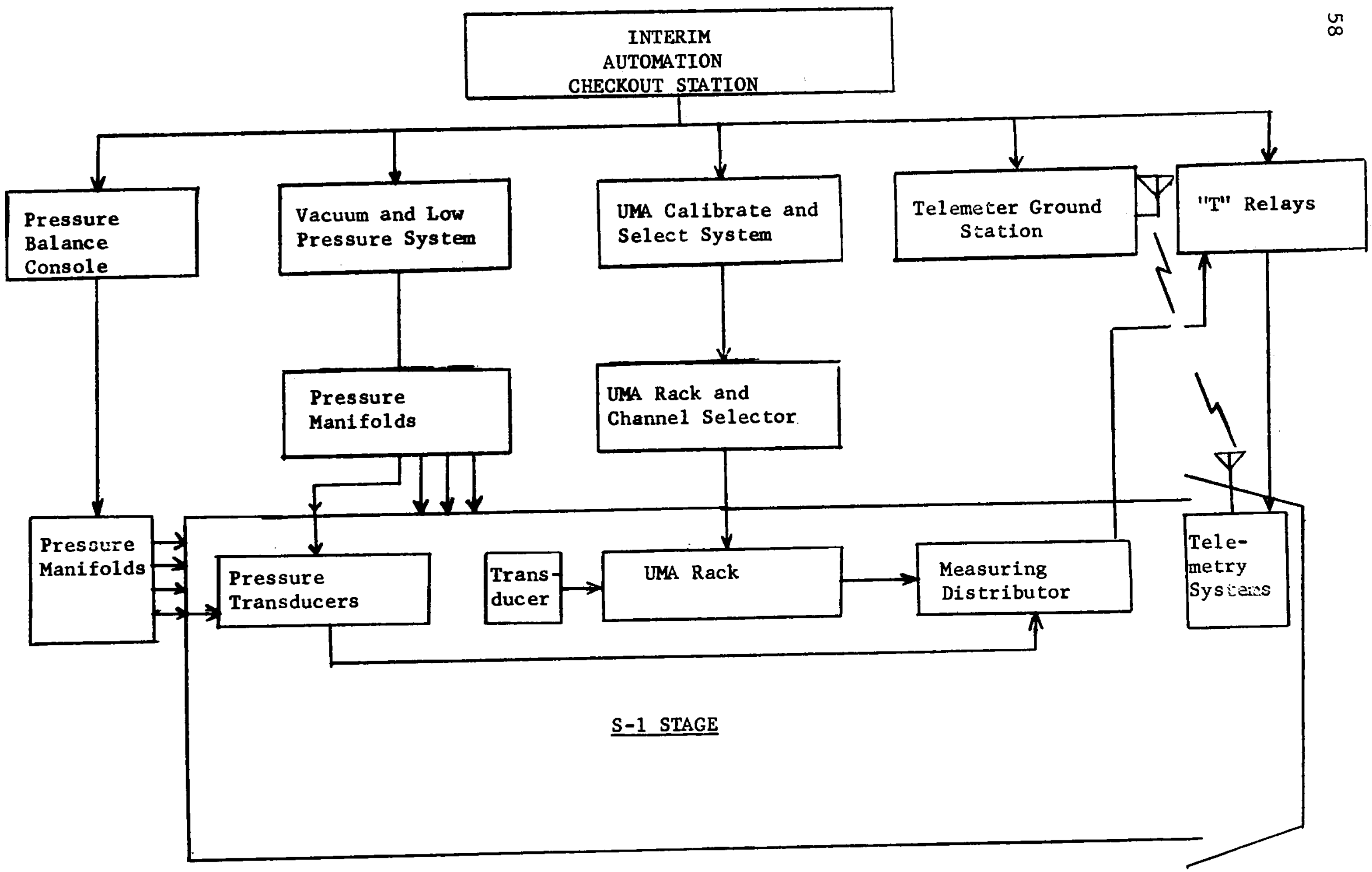


Figure 30.

TYPICAL TEST RESULT PRINT OUT

DATE	TIME OF DAY	ELAPSED TIME OF TEST	TEST STATION NO.
29 FEB 1960	0800	79 SEC	389
TEST NO.	LOWER LIMIT	MEASURED VALUE	UPPER LIMIT
000	7.996	7.997	7.997
001	23.96VDC	24.00VDC	24.05VDC
002	- 0.008VDC	- 0.001VDC	0.003VDC
003	23.94VDC	24.03VDC	24.06VDC
004	- 131.4VAC	- 113.5VAC	- 108.1VAC
005	- 26.77VDC	- 26.22VDC	- 26.23VDC
006	0.000MS	0.000MS	0.000MS
007	- 0.001MS	0.000MS	0.000MS
008	6.946VDC	7.047VDC	6.984VDC
009	6.946VDC	7.008VDC	6.984VDC
010	- 0.008VDC	- 0.007VDC	0.007VDC
011	- 0.008VDC	0.000VDC	0.003VDC
EOT END OF TEST			

Figure 31.

6. Automatic Equipment for Final Checkout at MSFC, C1

Figure 32 shows a general block diagram of the checkout facility being supplied to MSFC by Packard Bell. The stage computer complex consists of three general purpose computers (expandable to 10) communicating with one another by sharing common memory elements under a master-slave structure. With scheduling and priority control by the master computer, each slave computer communicates with any one of 10 test stations (expandable to 32). The hardware forms a closed loop system that provides stimuli generation, switching, and response retrieval, all under computer control. Transmissions between the computer and test stations are digital, permitting location of the test stations at a considerable distance (several thousand feet) from the computer complex.

a. Central Station

All computers used in the central station are rack-mounted PB 250's. These computers are used in the system in an unmodified version, permitting interchangeability and easy maintenance. The memory of each computer is expandable, by plug-in modules of 256 words, in increments up to approximately 16,000 words. Space is presently allotted for 10,000 words of memory for each computer. Slave master communications use 2560 words of the master computer memory. The word length is 24 bits, of which 22 are accessible to the programer. This computer has 12 microseconds add or subtract time, 276 microseconds multiply or divide time, and 264 microseconds square root. A variety of peripheral equipment is available to the central computer complex, including magnetic tape units, high speed paper tape readers, high speed tape puch, and two flexowriters. The magnetic and punched paper tape equipment is accessible only to the master computer, relieving the slave machines of the task of input/output via these methods. One flexowriter is operated through a buffering system identical to the test stations, whereas the other is switchable, thus permitting off-line operation of any computer.

b. Satellite Stations

Each satellite station is tailored to specific tasks as directed by the "building block" checkout approach. In this approach, tests of increasing coverage are performed, beginning at the component level, working up through subsystems and system levels, and

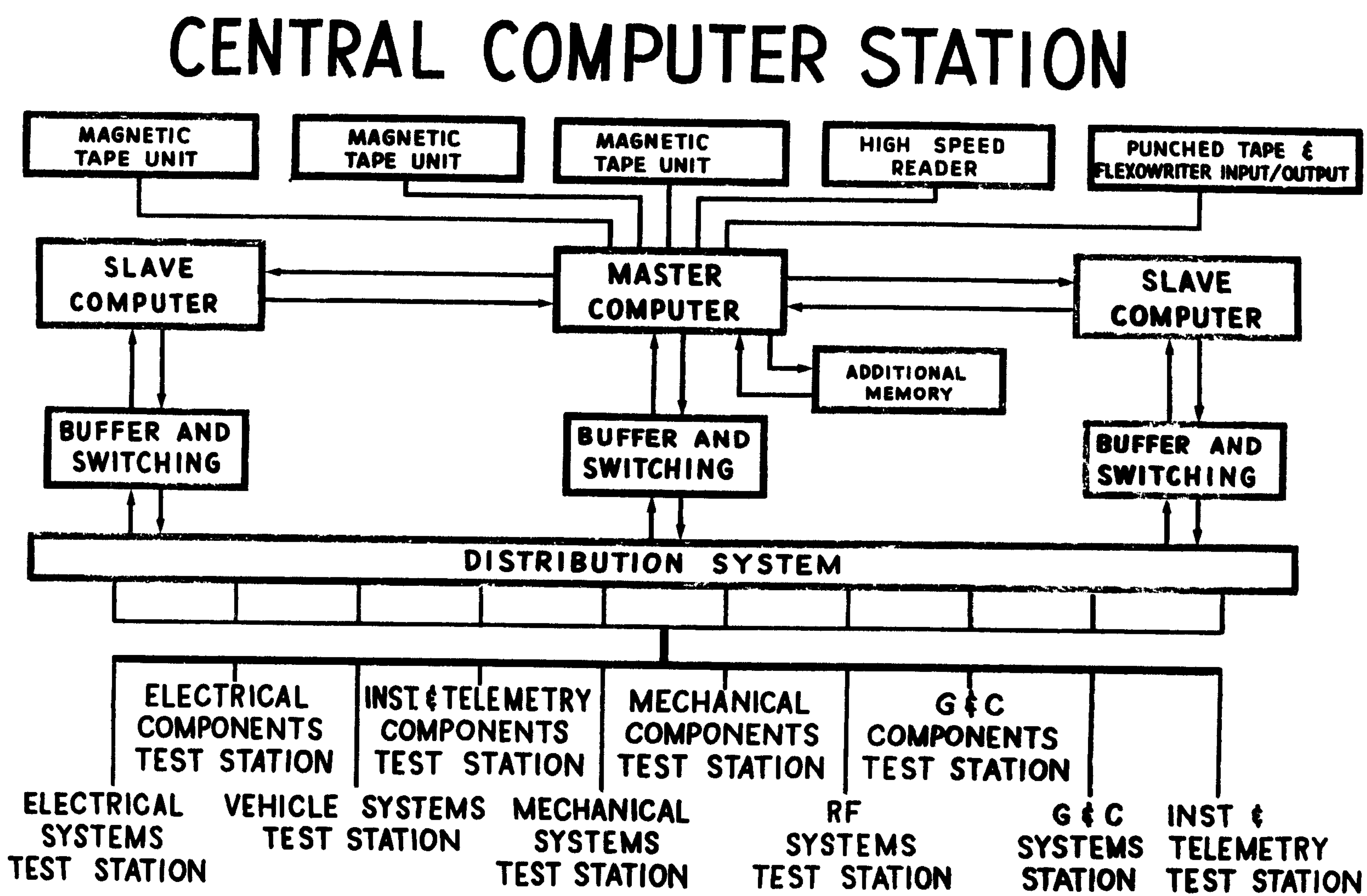

CENTRAL COMPUTER STATION
MAGNETIC TAPE UNIT
MAGNETIC TAPE UNIT
MAGNETIC TAPE UNIT
HIGH SPEED READER
PUNCHED TAPE & FLEXOWRITER INPUT/OUTPUT
SLAVE COMPUTER
MASTER COMPUTER
SLAVE COMPUTER
ADDITIONAL MEMORY
BUFFER AND SWITCHING
BUFFER AND SWITCHING
BUFFER AND SWITCHING
DISTRIBUTION SYSTEM
ELECTRICAL COMPONENTS TEST STATION
INST & TELEMETRY COMPONENTS TEST STATION
MECHANICAL COMPONENTS TEST STATION
G & C COMPONENTS TEST STATION
ELECTRICAL SYSTEMS TEST STATION
VEHICLE SYSTEMS TEST STATION
MECHANICAL SYSTEMS TEST STATION
RF SYSTEMS TEST STATION
G & C SYSTEMS STATION
INST & TELEMETRY TEST STATION

Figure 32.

eventually to tests involving the entire stage such as overall and composite tests. At the components and subsystem levels, one satellite station may be adequate to determine acceptability and conformance with specified operational characteristics, whereas the more complex overall and composite tests require the coordinated effort of several stations. The test stations include: instrumentation and telemetry systems and components; guidance and control systems; radio frequency systems; networks systems; electrical components; and mechanical systems, assemblies, and components.

In addition to the checkout equipment, each station contains an operator console, flexowriter, and various lights. Where necessary for remote use, up to eight portable indicators are available. An operator may carry the indicator as he performs manual operations onboard the vehicle, thus providing closed loop communication with the system. For manual adjustment, the indicator under computer control displays identification data for the piece of equipment concerned and shows whether the adjustment is high, low, or within limits. Two buttons are available to feed back operator requirements to the computer. One is normally used to cycle a piece of equipment as in the case of interacting adjustments; the other button indicates to the computer that the operator wishes to go on to the next piece of equipment. At this time the computer retains the most recent data if required for go no-go decision.

c. Digital Transmission and Buffering

Digital communications and computations within the central computer complex are at a 2 mc rate. Computer-to-station communications are at a slower 100 kc rate involving fewer transmission problems. To accommodate this difference in digital transmission rate and to provide parallel output at the station end, buffer registers are provided as indicated in Figure 1. Word length in general use is 22 binary digits exclusive of parity and guard.

d. Automatic Test Methods

Automatic checkout methods follow generally the concept of:

Stimuli (& stimuli path) $\rightarrow$ Unit under test $\rightarrow$ Response (& response path).

The 22-bit computer word sent to a test station is divided into three fields:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
ADDRESS							COMMAND			DATA											

Seven bits are allotted for 128 possible addressable subassemblies. Decoding the addresses enables display devices, switching matrices, programable power supplies, pressure generators, signal generators, positioning devices, analog-to-digital voltage converters, digital-to-analog voltage converters, and various other stimuli generators or response conditioners to function. The exact equipment in use varies from station to station and is tailored to specific tasks. Eight addresses are reserved for station communication (via flexowriter, numerical indicators, and lighted displays).

Three bits are allotted for commands. Of the eight available commands, five are presently used. These commands govern the emission of certain clock signals controlling the major operations (e.g., direction of data transfer) within the satellite test station.

Twelve bits of the format contain data. These are used in the enabled or addressed module to select specific elements or to control the level of operation. (These bits are also the preferred means for accepting digital data from the satellite test station; however, all 22 bits may be used to return data to the computer.) Twelve bits provide a general data resolution of one part in 2^{12} or 4096; however, this is not an absolute restriction. Multiple addressing can provide increased resolution or accuracy. For reasons of hardware standardization or simplicity, maximum data capability is not always utilized. In control of simple devices, optimum data usage if often not required.

7. Saturn C5 Checkout Program

The Saturn automation plan provides that checkout of individual stages of the C5 vehicle will be automated at the contractor's plant, at the static test site, and at the staging area of the launch site. Stage checkout must verify and ensure that the stage meets design specifications. It must mate compatibly with the other stages and with the automated launch ground support equipment for the integrated system.

The last requirement dictates that the checkout equipment for the individual stage be automated. Stage contractors have therefore been directed to design their checkout equipment based around control by a general-purpose digital computer complex. Further, since such a computer complex is available in the plant, test stations for automatic control of bench functional testing of "black boxes" will be provided.

Peculiarities of a contractor's facilities, organization, or background might prove to make one type of computer or system of operation more desirable than those used by different contractors. Each stage contractor will therefore propose to use the computers and checkout systems which appear best suited for the specific application. If a review by MSFC indicates that the proposed system agrees with the general automation concept and will satisfy the requirements for stage checkout, the contractor's proposals will be approved. This approach not only satisfies any pecularities of a contractor's operating conditions, but also provides for improvements of the state of the art plus valuable cross-feed of approaches and techniques.

Aside from the factors previously mentioned, there are three additional considerations which make is feasible to utilize different checkout equipment at stage checkout areas and at the launch site.

a. Launch-site GSE, which will be designed as an integral part of the vehicle-launch facility system, will contain very little stage-peculiar checkout equipment.

b. Usage of the same computer design for automatic checkout of Saturn-class vehicles and their stages might tax the facilities of any prospective computer manufacturer.

c. By using proper signal conditioning and buffering equipment, different computer designs can now be readily utilized for checking out the same equipment at different localities.

The general scheme is illustrated in Figure 33. It consists, essentially, of test stations, a computer complex, stage substitutes, and facility and specialized ground support equipment. Lines between test stations and the computer complex are digital links, in general.

SATURN STAGE CHECKOUT CONCEPT

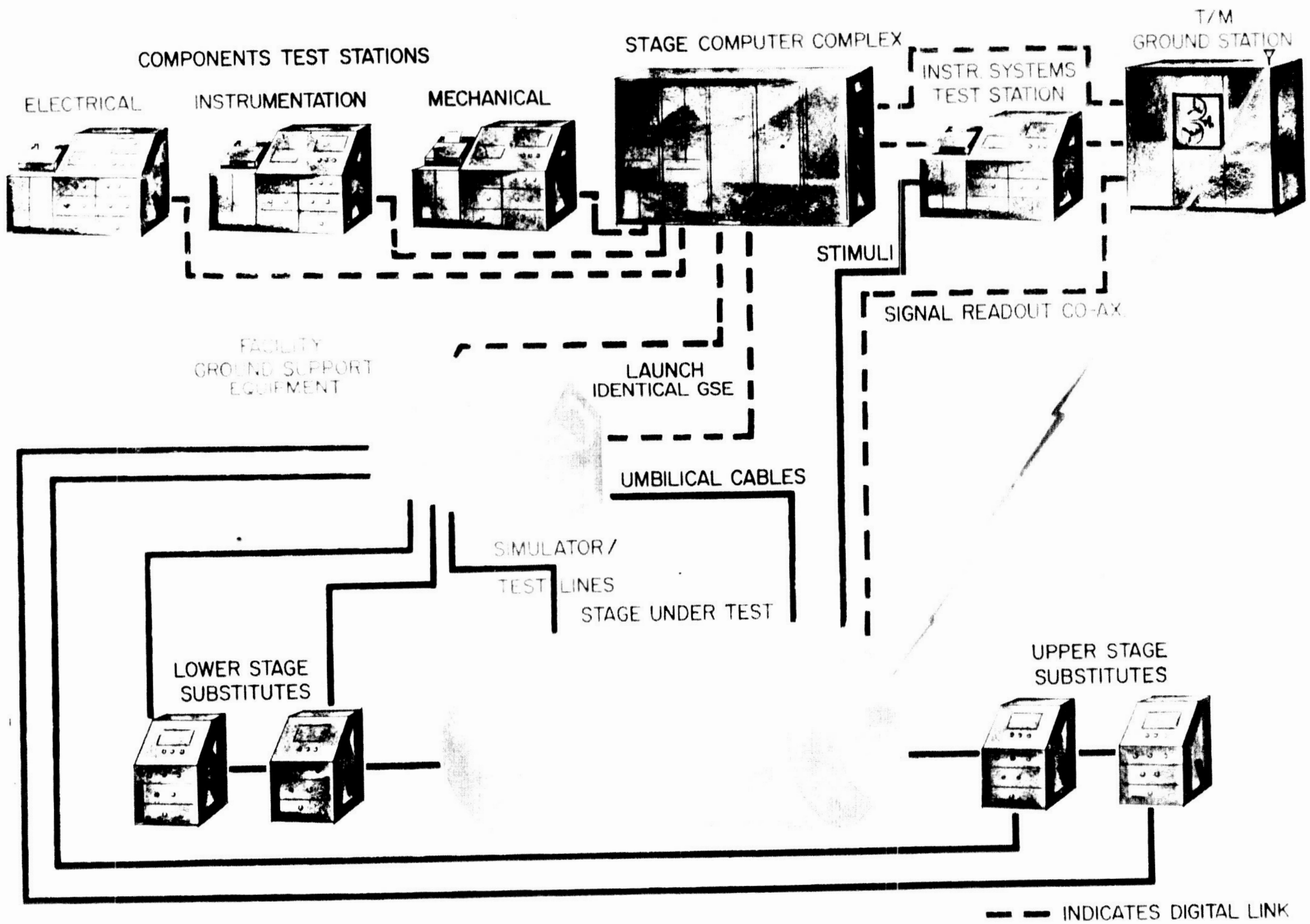


Figure 33.

a. Test Stations

Figure 29 includes blocks labeled test stations. It is intended that these be indicative rather than definitive, since the particular stations required can only be determined after the stage is defined; however, both component stations (for functional acceptance testing) and system stations (for vehicle checkout) are shown. All stations will be remotely controlled by the computer complex. Use of stations will be determined by executive program scheduling within the computer complex upon request for test from the stations. The density of the testing schedule will determine the degree of simultaneity of operation required and whether a number of computers are required in the computer complex. Each test station will contain the necessary equipment to furnish power, stimuli, and readback (mechanical and electrical) to perform the complete task required of that station. Stations will also provide monitoring capability for operator evaluation of test progress and results. Request for test, together with identification of test required and equipment to be tested, will originate from the test stations. Flexibility to allow for system or component changes with minimum test station changes will also be built into the stations; this will be accomplished with present state of the art, commercially available hardware.

The instrumentation system's test station is a group of equipment programable by computer control to furnish stimuli to the sensors and transducers of the stage flight-measuring systems. This test station will have such items as pneumatic supplies, power supplies, frequency supplies, variable gain amplifiers, switching matrix, etc.; all programable from the central complex.

It is also intended that this test station will furnish the interface between the telemeter ground station and computer, if required. This will vary with the system, depending on the type of telemeter system used and whether the output of the ground station is already converted to digital form.

b. Telemeter Ground Station

The telemeter ground station will be defined by the type of stage telemetering system or systems that will be used. In most cases there will be more than one type of telemeter system including a PCM type; however, the advantage of PCM will be fully utilized in the checkout and monitoring of the vehicle measuring systems. The PCM ground station design documentation will be supplied to the contractor.

c. Computer Complex

The computer complex, which is the test control center, shall consist of one or more general purpose digital computers. The number and size of the computers will be determined by stage and test simultaneity requirements. The computers used will be commercially available and will provide for recording of test results in standard IBM 729, Mod. II or IV, format in a manner such that the information can be used in the MSFC central data retrieval system. Provision will also be included for recording of operating time on major flight hardware. In general, the capability of the complex should be expandable or retractable in comparatively small increments. Bulk storage or previously certified test procedures will be utilized so that tests may be called out and supplied to test stations on request. Choice of computers to be used shall be from those defined by the MSFC Automation Board and as selected by the contractor and agreed upon by MSFC. Transfer of information between the computer complex and test stations shall be digital. The computer shall be capable of generating, under stored program control, signals for excitation of the test stations and of detecting signals generated by these stations.

d. Stage Substitutes

The blocks of equipment indicated as substitutes for the stages and payload are, in most cases, actually interface substitutes to demonstrate compatibility of the stage under test with other stages to which it must mate at the launch site. An exception to this will be the instrument unit substitute which will furnish signals for engine gimbaling during checkout.

e. Ground Support Equipment

This group of equipment depicts the stage identifiable GSE at the launch site, as defined previously, and also the supplementary equipment necessary for the checkout of the separated stages and integration of the stage checkout with the surrounding facility. The stage identifiable GSE will be specifically defined by MSFC in defining the launch equipment. The GSE will be automatically controlled by the computer complex and should be designed accordingly.

f. Staging Building Checkout Concept

Figure 33 illustrates the required stage checkout at the launch site staging building. The contractor will furnish the checkout equipment for his particular stage which shall be essentially the same as that used at the manufacturing plant for staging building operation. High firing rates demand a minimum of checkout and operational time at the launch site. Computer-controlled reproduction of the test procedures as performed at the manufacturing plant will quickly point out differences in results obtained at the launch site and deterioration of components and systems. Further, utilizing computer control and stage-identifiable ground support equipment as used for launch provides for a stage-ground support equipment environment at the plant that is as nearly like the launch site operation as is reasonably practical. This will provide the maximum assurance that the stage will mate properly and perform as intended during a launching operation.

E. DATA PROCESSING

Since an automated system is planned for the C1 and C5 operations (with the exception of the S-IV stage on C1), pertinent a l extensive data of extreme importance to design and reliability engineers must be rapidly processed. As a part of the general automation plan, a central data retrieval and data storage system has been planned at MSFC. This central data storage facility will not only provide services for processing automatic checkout data, but will also provide the same service for non-automated test and checkout data.

The facilities and an organization to handle the central data bank currently exist at MSFC as shown in Figure 34. Data will be received from inspection sources, from test and checkout data-generating divisions within MSFC and LOC, and from C1 and C5 stage contractors, including the S-IV stage contractor.

In view of the vast volumes of test and inspection data to be generated from the various vehicle stage areas, along with technical and administrative data, a study was conducted on a data center concept having random access memory capabilities and remote inquiry stations. Such a system with a transistorized computer was approved and will be installed at MSFC during November 1962. Remote inquiry stations or data links will be strategically located within MSFC divisions. If the need warrants, stage contractors' facilities can be linked to the data center.

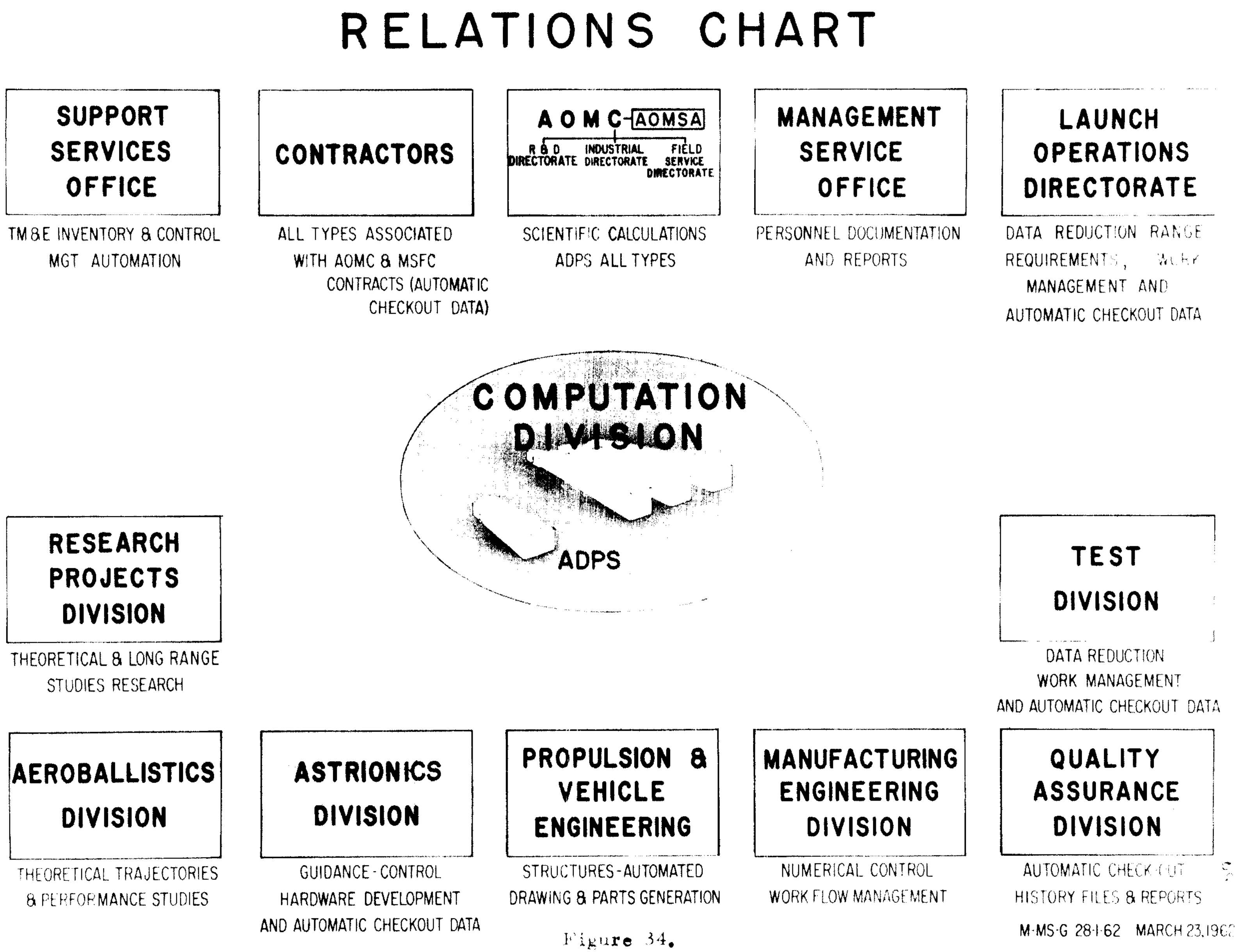

RELATIONS CHART
SUPPORT SERVICES OFFICE
TM&E INVENTORY & CONTROL MGT AUTOMATION
CONTRACTORS
ALL TYPES ASSOCIATED WITH AOMC & MSFC CONTRACTS (AUTOMATIC CHECKOUT DATA)
AOMC AOMSA
R & D DIRECTORATE
INDUSTRIAL DIRECTORATE
FIELD SERVICE DIRECTORATE
SCIENTIFIC CALCULATIONS ADPS ALL TYPES
MANAGEMENT SERVICE OFFICE
PERSONNEL DOCUMENTATION AND REPORTS
LAUNCH OPERATIONS DIRECTORATE
DATA REDUCTION RANGE REQUIREMENTS, WORK MANAGEMENT AND AUTOMATIC CHECKOUT DATA
COMPUTATION DIVISION
ADPS
RESEARCH PROJECTS DIVISION
THEORETICAL & LONG RANGE STUDIES RESEARCH
TEST DIVISION
DATA REDUCTION WORK MANAGEMENT AND AUTOMATIC CHECKOUT DATA
AEROBALLISTICS DIVISION
THEORETICAL TRAJECTORIES & PERFORMANCE STUDIES
ASTRIONICS DIVISION
GUIDANCE-CONTROL HARDWARE DEVELOPMENT AND AUTOMATIC CHECKOUT DATA
PROPULSION & VEHICLE ENGINEERING
STRUCTURES-AUTOMATED DRAWING & PARTS GENERATION
MANUFACTURING ENGINEERING DIVISION
NUMERICAL CONTROL WORK FLOW MANAGEMENT
QUALITY ASSURANCE DIVISION
AUTOMATIC CHECKOUT HISTORY FILES & REPORTS
M-MS-G 281-62 MARCH 23,1962

Figure 34.

Special typewriters and card or tape machines will be located at the remote inquiry stations and tied directly to the centralized computer by direct line hard wire or microwave circuits as depicted in Figure 35. They will be able to transmit and receive data to and from the data center at speeds dictated by project urgency. Typical data center input and output reports are shown in Figures 36 and 37.

Several aspects of the data processing program must be resolved, such as transmission of data, format, printout, data coding, type of data to be stored, etc., before a central data retrieval and storage facility can become operational. The data format will be IBM 729, Mod II and Mod IV binary coded decimal, on seven-channel magnetic tape, with a density of 200 or 556 bits per inch. In data generating areas where facilities are not available for recording on magnetic tape, a media of IBM punched paper tape and/or cards will be used. Data printout from the data bank to the using agency will be displayed in tabulated report form. Other requirements, such as coding for the central computer and arranging of sequence for printout, etc., will be resolved within the immediate future.

The sources of data to be stored in the centralized data bank have been grouped in the following four broad areas: (1) data from components and assembly inspection, (2) data from bench test functional testing, (3) data from stage and vehicle systems testing, and (4) data from failure reports. With the broad areas defined, it will be determined what information will be recorded and stored.

From inspection records, quality assurance information regarding parts and assemblies will be stored. For bench functional testing of assemblies and for complete stage or vehicle testing, information regarding mechanical functions, electrical functions, sequences of events, etc., will be stored. For failure reports, information will be stored concerning types of failure, conditions of failure, life cycles, etc. The data center will be able to consolidate bits of information from the various reports and to produce comprehensive consolidated reports to divisions having needs for such reports. Their value from both the design and reliability standpoints are obvious.

In addition to the test information stored, information will be included regarding component, assembly or measurement numbers and descriptions, test dates, test numbers, serial numbers, lot numbers, etc. Classifying information for each of the four broad sources

DATA CENTER CONCEPT

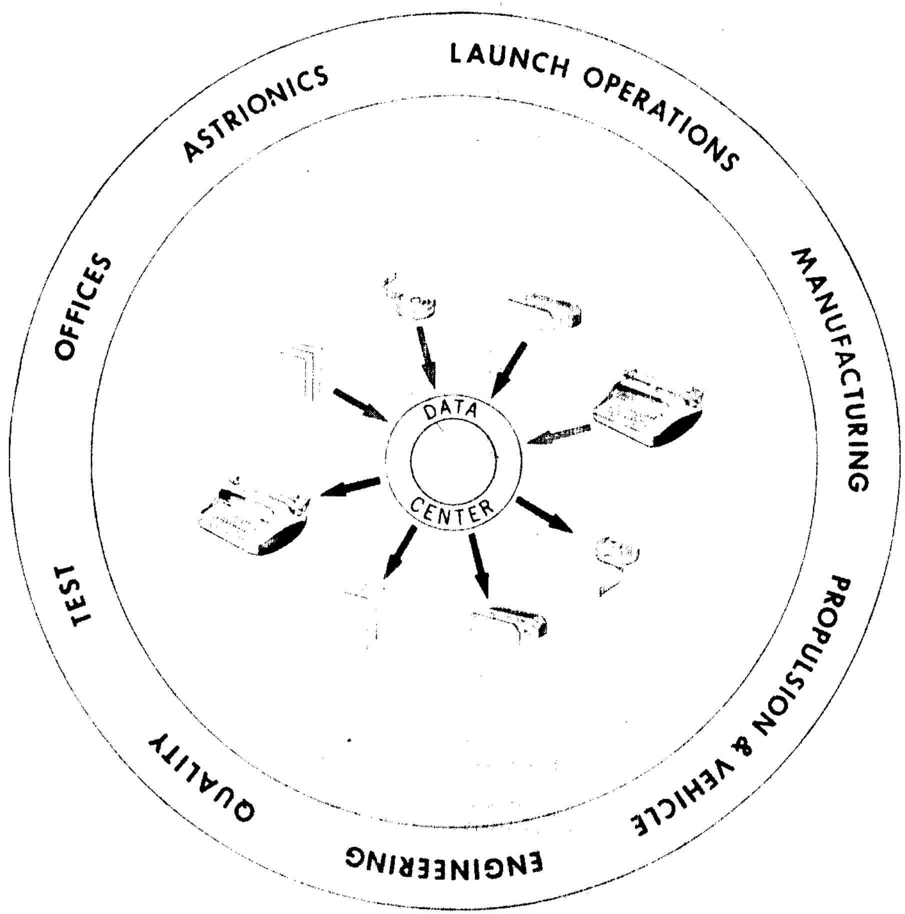


Figure 35.

TYPICAL DATA CENTER INPUT

ASTRIONICS /PROP. & VEH. ENG.	MFG. ENG.	QUAL. ASSURANCE	TEST	LOD	ADMINISTRATIVE PROC	ADMINISTRATIVE TMB	ADMINISTRATIVE FINANCIAL	OUT OF HOUSE OPERATION
1. MASTER DRAWING LIST 2. DRL'S PARTS LISTS 3. ELEC. EQUIP. LISTS 4. EFFECTIVITY 5. QUANTITY 6. WEIGHTS 7. FIND NUMBER 8. INSTRUMENTATION INFO. 9. REVISIONS 10. ENG. ORD. NO.	1. W.O. INFO. 2. PARTS OR ASSY'S APPLIED 3. E.O. WAIVERS 4. INST. APPLIED 5. TOOLING INFO.	1. UCR 2. DEF. RPTS. 3. PARTS ACCPT. 4. TEST RSLTS 5. INSP. SPEC. 6. TEST PROC. 7. INST. TEST AND CAL.	1. UCR 2. DEF. RPT. 3. STATIC TEST DATA 4. TEST PROC.	1. UCR 2. DEF. RPT. 3. TELE. RSLTS. 4. FLIGHT DATA 5. TEST PROC.	1. DATE DUE 2. VENDOR 3. REVISED QUANTITY.	1. BAL. ON HAND 2. DUE IN 3. DUE OUT 4. PRIORITIES	1. BUDGET BREAKDOWN AND RE-QUIREMENTS 2. CERTAIN BUDGET EN-TRIES AND CHANGES	1. SIMILAR INFO. FROM CON-TRACTORS
* SPECIAL ITEM INFO.	* SPECIAL ITEM INFORMATION	* SPECIAL ITEM INFO.	* SPECIAL ITEM INFO.	* SPECIAL ITEM INFO.	* SPECIAL ITEM INFO.	* SPECIAL ITEM INFO.	* SPECIAL ITEM INFO.	* SPECIAL ITEM INFO.

705 COMPUTERS 7090 COMPUTERS 1401 COMPUTERS
DATA CENTER (COMPUTER EQUIP.)

***COMPUTER SERVICES
PROGRAMMING & SYSTEMS
ANALYSIS BY COMP. DIV.

* SPECIAL ITEM INFO.
OPERATING TIMES
ITEMS AGREED NOT TO BE ON
ITEMS NOT ON FOR PRE-STATIC
ITEMS NOT ON FOR TEST
ITEMS WAIVERED
ITEMS NOT ON FOR SHIPMENT
ITEMS NOT ON FOR POST-STATIC
SPARE INFO.
STANDARD CODES
SCHEDULING DATA
OBSOLESCENCE

Figure 36.

TYPICAL DATA CENTER OUTPUT

*** COMPUTER SERVICES
PROGRAMMING & SYSTEMS
ANALYSIS BY COMP. DIV.

ASTRIONICS PROP. & VEH. ENG.	MFG. ENG.	QUAL. ASSURANCE	TEST	LOD	PROC.	TMB.	FINANCIAL	GENERAL REPORTS
1. E.O. COMPLIANCE WAIVER LIST. 2. INSTRUMENT COMPLIANCE 3. TOOLING INFO. 4. DESIGN DEFECT LISTING 5. QUALIFIED PARTS LIST * SPECIAL PARTS INFO.	1. ASSY. STATUS OF VEHICLE 2. PARTS LIST FOR W/O 3. PROC. DETER-MINATION 4. MASTER DR. LIST 5. E.O. STATUS LIST 6. INSTR. STATUS LIST 7. FAB DEFECTS * SPECIAL PARTS INFO.	1. STATUS OF VEHICLE 2. APPROVED VENDOR LIST 3. E.O. WAIVER & COMPLIANCE STATUS 4. INSTR. STATUS 5. INSP & TEST REPORTS 6. TEST PROC. 7. MASTER DR LIST * SPECIAL PARTS INFO.	1. STATUS OF VEHICLE 2. DIFF. FROM LAST VEHICLE 3. E.O. STATUS & WAIVERS 4. INSTR. STATUS 5. MASTER DR. LIST * SPECIAL PARTS INFO.	1. STATUS OF VEHICLE 2. SHIPPING INFO. 3. E.O. STATUS & WAIVERS 4. DEF. & UCR SUMMARY 5. MASTER DR. LIST * SPECIAL PARTS INFO.	1. PROC. RE-QUIREMENTS 2. IMMEDIATE CHANGE INFO. 3. ADDITIONAL PROC. TIME	1. MORE TIMELY PLANNING DATA 2. WEIGHTS & CUBE 3. ITEM LOCATION 4. ADVANCED CATALOGUE INFO.	1. DIRECT LABOR 2. OVERHEAD 3. PARTS EXPEND-ITURE 4. SUPPLY COST 5. EQUIP. COST 6. RENTAL COST 7. TOTAL BUDGET STATUS	1. REPORTS TO CONTR. 2. DEF. & UCR ANALYSIS 3. ANALYSIS OF TEST RSLTS. 4. VEHICLE HIST. SUMMARY 5. FLIGHT EVALUATION

Figure 37.

of test data will be issued as a specification to all MSFC divisions and to stage contractors in the interest of maximum standardization. Figure 38 shows a number of advantages which will be realized by utilizing an integrated data system.

SECTION II. PROGRAM IMPLEMENTATION

A forthcoming document will go into considerable detail concerning the implementation of the automation plan. Organizational responsibilities, control and reporting procedures, development schedules, and, if possible, applicability to orbital operations will be documented.

The following sections are presented as working papers for the sole purpose of offering advance information concerning the implementation plan. For example, Section I of this report dealt almost exclusively with the overall objectives of the automation program and with the computer and data acquisition systems around which automatic checkout systems must be developed. Therefore, little attention was given, for example, to the immense challenge presented by the need for automating the checkouts of the mechanical systems of space vehicles. The following section outlines MSFC's approach to automation of electromechanical systems.

A. ELECTROMECHANICAL AUTOMATION

To enhance the probability of mission success for operational C1 and C5 vehicles, it is essential that the vehicle contain provisions for remote, automatic, mechanical systems checkout and testing for critical components and subsystems. For rendezvous-type missions, this requirement becomes mandatory. Mechanical automation is defined as the use of mechanical, pneumatic, hydraulic, electrical and electronic equipment capable of making automatic decisions by continuous programing and monitoring of vehicle components and systems during checkout and tests. The system should be capable of furnishing its own stimuli and contain provisions for self-monitoring.

The electromechanical automation subboard is documenting mechanical systems test and checkout procedures for use at the launch site and in the vertical assembly facility. The subboard will recommend the extent to which these procedures can be incorporated in an automatic systems test and checkout. Two parallel efforts are being utilized for

WHY?--AN INTEGRATED DATA SYSTEM

1. ELIMINATE DUPLICATION OF EFFORT & SYSTEMS INCOMPATIBILITY
2. MINIMIZE MANUAL EFFORT
3. ACCURACY ASSURANCE
4. LATEST DATA AVAILABLE TO ALL DIVISIONS & TOP MANAGEMENT
5. METHODS STANDARDIZATION
6. GUIDANCE TO OUT-OF-HOUSE CONTRACTORS
7. MAXIMUM USE OF DATA PROCESSING TECHNIQUES
8. CENTER SYSTEMS MANUAL DEVELOPMENT & CODING

Figure 38.

establishing electromechanical automation requirements for the S-I and S-IC stages. The first is based on a review of existing Saturn mechanical systems checkout and test procedures by experienced designers and users. The second effort, which is being used to establish minimum electromechanical automation requirements, is presented in detail in Marshall Technical Paper* MTP-P&VE-E-62-2 titled "A Generalized Approach for Systems Design Analysis and Selection of Components for Automation." The approach for systems design analysis and selection of components for mechanical automation will be accomplished in two phases. The effort will provide a documented, single failure effect analysis and a criticality ranking of all mechanical components in the vehicle/launch complex system.

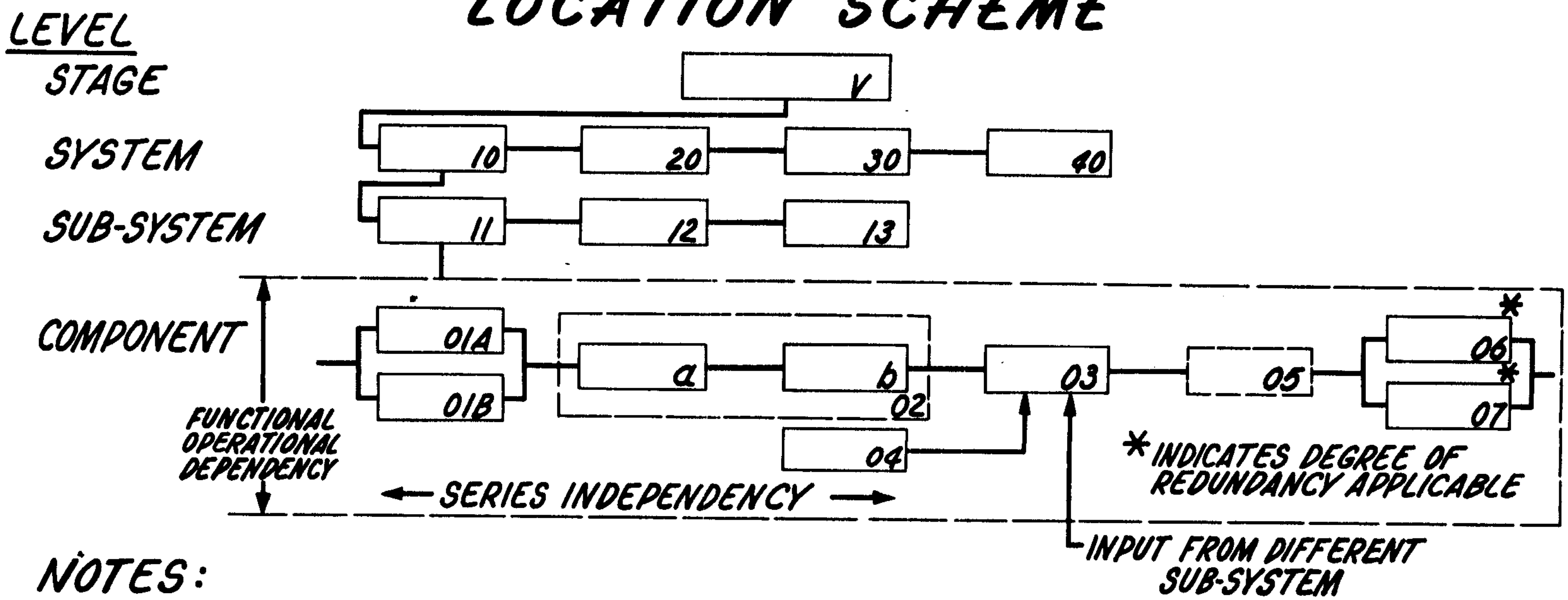
A symbolic logic block diagram indicating series independency and functional dependency of components in a typical mechanical system is shown in Figure 39. While the block diagram defines subsystems and identifies functional components, it is not a functional schematic or an energy flow diagram. It is used only for early systems' analysis and to point out weak links which might impair systems' performances. Such diagrams indicate which items will be operational and which will be non-operational during flight. They should also point out where redundant provisions can be incorporated in systems designs.

A single failure effect analysis must be performed for each block in the symbolic logic block diagram. The failure effect analysis indicates the effect of component failures on subsystems or systems performance. It also points out the effect on the stage and the vehicle should failure occur during launch countdown or during flight. In determining the effect of a component failure on subsystem performance, the four modes of failure shown in Figure 40 are considered.

The symbolic logic block diagram for the oxidizer pressurization system and the standard format adopted by MSFC for single failure effect analyses are presented in Figures 41 and 42. For analysis purposes, the effects of a component failure on the subsystem or system will be classified in the failure effect analysis as follows:

Effect of Component Failure	Probability of Loss
Actual loss	100%
Probable loss	50%
Possible loss	10%
None	0%

GENERAL SYMBOLIC LOGIC BLOCK LOCATION SCHEME



NOTES:

1. STAGE IS DEPENDENT ON 10, 20, 30 & 40; FOR THE STAGE TO OPERATE, SYSTEMS 10, 20, 30 & 40 MUST FUNCTION.
2. SYSTEM 10 IS DEPENDENT ON 11, 12 & 13; FOR THE SYSTEM TO OPERATE, SUB-SYSTEMS 11, 12 & 13 MUST FUNCTION.
3. SUB-SYSTEM 11 IS DEPENDENT ON 01A, 01B, 02, 03, 05, 06 & 07; FOR THE SUB-SYSTEM TO OPERATE, THESE COMPONENTS IN SERIES MUST FUNCTION.
4. COMPONENTS 01A & 01B ARE IDENTICAL, REDUNDANT FOR ALL FAILURE MODES UNLESS OTHERWISE INDICATED (SEE NOTE 8).
5. COMPONENT 02 CONSISTS OF TWO SEPARABLE COMPONENTS a & b, BUT HAS ONLY ONE PART NUMBER.
6. COMPONENT 03 IS FUNCTIONALLY/OPERATIONALLY DEPENDENT ON BOTH COMPONENT 04 AND ANOTHER SUB-SYSTEM.
7. COMPONENT 05 IS NOT OPERATIONAL DURING FLIGHT.
8. COMPONENTS 06 & 07 INDICATE STANDBY SAFETY CIRCUIT. COMPONENT 06 OPERATES ONLY WHEN 07 FAILS IN SPECIFIED MODE.

Figure 39.

SINGLE FAILURE EFFECTS ANALYSIS

THE FOUR MODES OF FAILURE CONSIDERED:

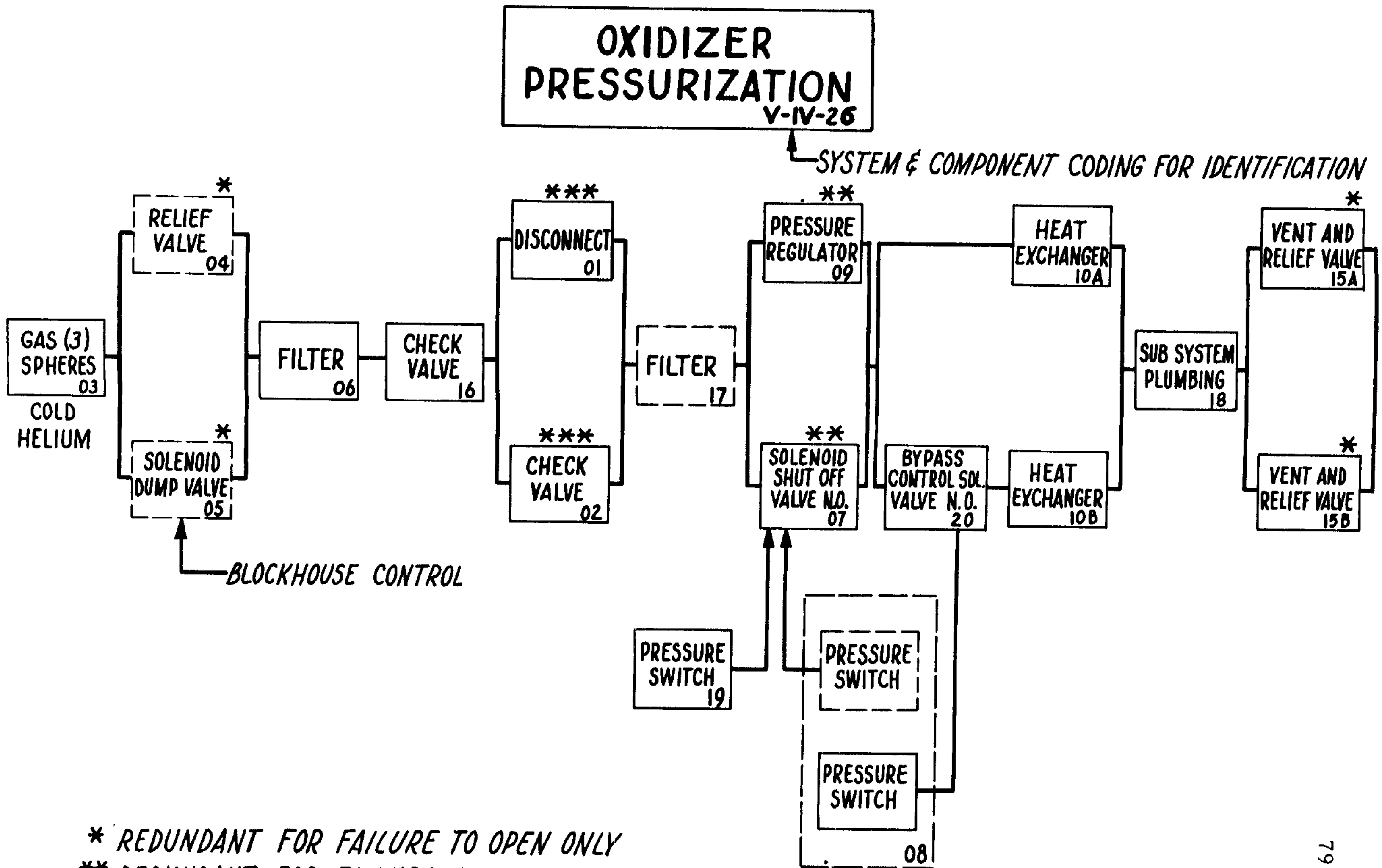
a. PREMATURE OPERATION OF COMPONENT.

b. FAILURE OF COMPONENT TO OPERATE AT PRESCRIBED TIME.

c. FAILURE OF COMPONENT TO CEASE OPERATION AT PRESCRIBED TIME.

d. FAILURE OF COMPONENT DURING OPERATION.

Figure 40.



* REDUNDANT FOR FAILURE TO OPEN ONLY
** REDUNDANT FOR FAILURE TO CLOSE ONLY FOR 26-09
*** REDUNDANT FOR FAILURE TO CLOSE ONLY

Figure 41.

FAILURE EFFECT ANALYSIS
OXIDIZER PRESSURIZATION SUBSYSTEM

A. LAUNCH CONDITION
B. FLIGHT

ITEM	**	P/N	FUNCTION	FAILURE TYPE	FAILURE EFFECT ON SUBSYSTEM	FAILURE EFFECT ON S-IV STAGE	FAILURE EFFECT ON C-I VEHICLE
GAS SPHERES(3) (COLD HELIUM)		7851834-1	PROVIDES STORAGE FOR HIGH PRESSURE GASEOUS HELIUM (3200 PSIG MAX) GAS SPHERES ARE SUBMERGED IN LIQUID HYDROGEN	1. EXTERNAL LEAK AT CONNECTION	POSSIBLE LOSS CONTINUOUS LOSS OF PRESSURIZING GAS MAY DEPLETE COLD HELIUM SUPPLY PRIOR TO MISSION COMPLET-ION	A. LAUNCH DELAY OR RESCHEDULE B. POSSIBLE LOSS OF S-IV STAGE	A. LAUNCH DELAY OR RESCHEDULE B. POSSIBLE LOSS OF C-I VEHICLE
RELIEF VALVE	*	7851842-1	RELIEVES COLD HELIUM SUPPLY PRESSURE IN EXCESS OF 3250 ± 100 PSIG	1. INTERNAL LEAKAGE (LEAKAGE OVERBOARD)	POSSIBLE LOSS CONTINUOUS LOSS OF PRESSURIZING GAS MAY DEPLETE COLD HELIUM SUPPLY PRIOR TO MISSION COMPLET-ION	A. LAUNCH DELAY OR RESCHEDULE B. POSSIBLE LOSS OF S-IV STAGE	A. LAUNCH DELAY OR RESCHEDULE B. POSSIBLE LOSS OF C-I VEHICLE
				2. FAILURE TO OPEN	NONE; REDUNDANT SOLENOID VALVE CAN BE USED TO DUMP PRESSURE	A. NONE; REDUNDANCY PROVIDED B. NONE; NOT OPERATIONAL IN FLIGHT	A. NONE B. NONE

** ITEMS MARKED (*) DO NOT OPERATE IN FLIGHT

Figure 42.

Based on the single failure effect analysis, both launch-critical and flight-critical items lists will be prepared. They will list items covered by the failure effect analysis whose single failure would result in the probability of vehicle loss. Figure 43 shows the standard form adopted by MSFC for critical items lists as applied to an oxidizer pressurization system. Since the failure effect analysis does not distinguish between catastrophic and non-catastrophic losses, but only considers the degree of probability, this distinction must be made during the selection of critical items. For these items, vehicle loss probability will be shown with color codes. In addition, the remainder of the column shall be cross-hatched to represent the catastrophic vehicle loss probability. The reaction time (the estimated time elapsed from a component failure to loss of vehicle, i.e., 0.1, 1, 10, 100, etc., seconds) is also included.

Where a component has more than one type of failure mode, which would result in the probability of vehicle loss, separate entries will be made in the critical items list for each type of failure.

From the symbolic logic block diagram, the critical items list and the criticality ranking (Figures 41, 43, and 44, respectively), and by using the criteria presented in Figure 45, the minimum electromechanical automation requirements and a priority listing for possible automation of other components are established.

For the oxidizer pressurization subsystem shown, the minimum automation requirements and their basis for selection are:

Component	Code	Basis for Automation
Pressure Switch	26-08	Control functional dependent item whose failure will result in vehicle loss.
Vent and Relief Valve	26-15	Failure to close will result in catastrophic loss of the vehicle.

These automation requirements should be independent of both program schedules and cost. In addition, a minimum prelaunch checkout or monitoring basis is established for all critical items, especially for their critical failure modes, to be considered in preparing functional systems tests.

FLIGHT CRITICAL ITEMS LIST

SYSTEM	SUBSYSTEM	ITEM	ITEM CODE	TYPE OF FAILURE	LOSS EFFECT ON VEHICLE: CATASTRO-PHIC	ACTUAL 100%	PROBABLE 50%	POSSIBLE 10%	REACTION TIME (SECONDS)
PROPULSION V-IV-20	OXIDIZER PRESSURIZATION V-IV-26	GAS SPHERE	26-03	EXTERNAL LEAK AT CONNECTION					N/A
		RELIEF VALVE	26-04	INTERNAL LEAKAGE					N/A
		SOLENOID DUMP VALVE	26-05	INTERNAL LEAKAGE					N/A
		FILTER	26-06	IMPLOSION OF ELEMENT.					N/A
		SOLENOID SHUT-OFF VALVE, N.O.	26-07	FAILURE TO STAY CLOSED WHEN ENERGIZED					N/A
		SOLENOID SHUT-OFF VALVE, N.O.	26-07	FAILURE TO OPEN WHEN DE-ENERGIZED					1.0
		PRESSURE SWITCH	26-08	FAILURE TO DE-ACTIVATE					N/A
		PRESSURE REGULATOR	26-09	FAILURE TO OPEN					1.0
		HEAT EXCHANGER	26-10	COIL BURN THROUGH AT HOT SPOT					N/A
		VENT & RELIEF VALVE	26-15	FAILURE TO CLOSE DURING S-IV POWERED FLIGHT					1.0
		PLUMBING	26-18	LEAKAGE AT CONNECTION					N/A
		BY-PASS CONTROL SOLENOID VALVE, N.O.	26-20	FAILURE TO OPEN WHEN DE-ENERGIZED					N/A
		VENT & RELIEF VALVE	26-15	FAILURE TO CLOSE DURING S-I POWERED FLIGHT					1.0

Figure 43.

CRITICALITY RANKING

ITEM	FAILURE TYPE	STAGE LOSS PROBABILITY	FAILURE MODE FREQ RATIO	UNRELIABILITY	CRITICALITY NUMBER
GAS SPHERE (3) COLD HELIUM	① EXTERNAL LEAK AT CONNECTION	10%	1	.00030	[10 FOR SINGLE ITEM] 30
RELIEF VALVE	① INTERNAL LEAKAGE	10	9/10	.00370	333
	② FAILURE TO OPEN	0	1/10		
SOLENOID DUMP VALVE, N.C.	① INTERNAL LEAKAGE	10	3/4	.00183	137
	② FAILURE TO OPEN	0	1/4		
FILTER	① IMPLOSION OF ELEMENT	10	1	.00002	2
FILTER	① " "	0	1	0	0
CHECK VALVE	① INTERNAL LEAKAGE	0	1	.00370	0
CHECK VALVE	① " "	0	1	.00370	0
DISCONNECT	① INTERNAL LEAKAGE	0	1	.00370	0
	② FAILURE TO CLOSE AT DISCONNECT	0	1		
PRESSURE REGULATOR	① FAILURE TO OPEN	100	1/2	.01660	8300
	② " " CLOSE	0	1/2		
SOLENOID SHUT-OFF VALVE, N.O.	① FAILURE TO STAY CLOSED WHEN ENERGIZED	50	3/4	.00366	2287
	② " " OPEN WHEN DEENERGIZED	100	1/4		
PRESSURE SWITCH	① FAILURE TO ACTIVATE	0	1/2	.00333	0
	② " " DEACTIVATE	0	1/2		
HEAT EXCHANGER (A and B) [HELIUM COILS ONLY]	① COIL BURN THROUGH AT HOT SPOT	50	1	.00010	[50 FOR SINGLE ITEM] 100
BY-PASS CONTROL SOLENOID VALVE, N.O.	① FAILURE TO STAY CLOSED WHEN ENERGIZED	0	3/4	.00366	91
	② " " OPEN WHEN DEENERGIZED	10	1/4		
PRESSURE SWITCH	① FAILURE TO ACTIVATE	0	1/2	.00333	167
	② " " DEACTIVATE	10	1/2		
SUBSYSTEM PLUMBING	① LEAKAGE AT CONNECTIONS	10	1	.00011	11
VENT and RELIEF VALVE	① FAILURE TO OPEN	0	1/8	.00500	8750 (4375 for SINGLE ITEM)
	② " " CLOSE	100	7/8		

Figure 44.

CRITERIA FOR MECHANICAL AUTOMATION

A. ALL ITEMS WHOSE FAILURE MODE RESULTS IN A CATASTROPHIC LOSS WHICH CANNOT BE DESIGNED OUT-RECOMMEND AUTOMATION.

B. ALL ITEMS WHICH CONTROL FUNCTIONAL DEPENDENT ITEMS AND WHOSE FAILURE RESULTS IN A LOSS, AND WHOSE FAILURE MODE CANNOT BE DESIGNED OUT-RECOMMEND AUTOMATION AND REDUNDANT, STANDBY OR SAFETY ITEMS OR SUBSYSTEMS.

C. ALL REMAINING ITEMS WHOSE FAILURE MODE RESULTS IN A LOSS, ESTABLISH THRU MSFC A CRITICALITY FIGURE, ABOVE WHICH AUTOMATION AND/OR REDUNDANCY IS RECOMMENDED.

(BASED ON SCHEDULES & FUNDS)

Figure 45.

Figure 46 presents established major milestones for the automation of mechanical systems for the S-IC stage. In addition, milestones are shown for the launch complex and for general research and development activities associated with the automation of mechanical systems.

The techniques outlined in MTP-P&VE-E-62-2 for identification of minimum automation requirements are being implemented under MSFC direction and follow-on in the following programs:

Saturn C1 Program	Supporting Organization
Complex	MSFC
S-I Stage	MSFC
Instrument Unit	MSFC

Saturn C5 Program	Supporting Organization
Complex	MSFC - Boeing
S-IC Stage	MSFC - Boeing
F-1 Engine	MSFC - Rocketdyne
S-II Stage	North American Aviation
S-2 Engine	MSFC - Rocketdyne
S-IVB Stage	Douglas Aircraft
Instrument Unit	MSFC

B. AUTOMATIC CHECKOUT SYSTEMS DEVELOPMENT SCHEDULES

Figures 47 and 48 depict certain milestones in the program for automating checkout and launch control operations for the C1 vehicle. Figures 49 and 50 show similar milstones for the C5 program. The particular events shown and the dates proposed are offered as suggestions only. Comments concerning their applicability and timing will be welcomed by the technical staff, MSFC Automation Board. Additional milestones are particularly solicited. The milestones will not become official until they have been approved by the Automation Board.

The events listed in the four charts mentioned above are largely self-explanatory. However, the following definitions are presented for several terms whose meanings require clarification.

SATURN C-5 ELECTRO-MECHANICAL AUTOMATION CONCEPTUAL DESIGN PROGRAM

MILESTONES	AREAS OF RESPONSIBILITY			DESIGN REVIEW SCHEDULE	
	DIRECT	SUPPORT	FOLLOW ON	START	COMPLETE
1. ESTABLISH PROGRAM OBJECTIVES	M-AUTO	MSFC	MSFC	AUG 61	OCT 61
2. STAGE SYSTEMS (S-IC TYPICAL)	M-AUTO			OCT 61	JUN 62
A. ENVIRONMENTAL CONTROL	M-P&VE/ASTR	BOEING/MSFC	MSFC		
B. PNEUMATIC	M-P&VE				
C. HYDRAULIC	M-ASTR/P&VE				
D. PROPELLANT FILL & DRAIN	M-P&VE				
E. CONTAINER PRESSURIZATION	M-P&VE	BOEING/MSFC		OCT 61	JUN 62
F. ENGINE	M-P&VE/OEM	ROCKETDYNE	MSFC	JAN 62	AUG 62
3. LAUNCH COMPLEX SYSTEMS	M-AUTO				
A. FACILITIES (PROPELLANTS, PNEUMATICS, ENVIRONMENTAL CONTROL)	M-LOD	CONTRACTOR	MSFC	OCT 61	JUN 62
B. PERIPHERAL GSE (ENGINE SERVICE & C/O, REGULATED PRESSURE SUPPLY)	M-ASTR	M-LOD	MSFC	OCT 61	JUN 62
4. R & D PROGRAMS					
A. LEAK DETECTION					
RADIOACTIVE TRACER / DETECTOR	MSFC	UNIV. OF MICH.	MSFC	JAN 62	JUL 62
STATE OF THE ART REVIEW	MSFC	OHIO UNIV.	MSFC	JAN 62	JUL 62
DOUBLE SEAL FLANGE STUDY	MSFC	M-P&VE	M-P&VE	CONTINUING	
B. ACOUSTICAL MONITORING TECHNIQUES	MSFC	MSFC	MSFC	CONTINUING	
C. SERVO-CONTROL REGULATORS	MSFC	SERVO-MECHANISMS INC	MSFC	JAN 62	JUL 62

Figure 46.

C-1 AUTOMATIC CHECKOUT SYSTEMS DEVELOPMENT SCHEDULE

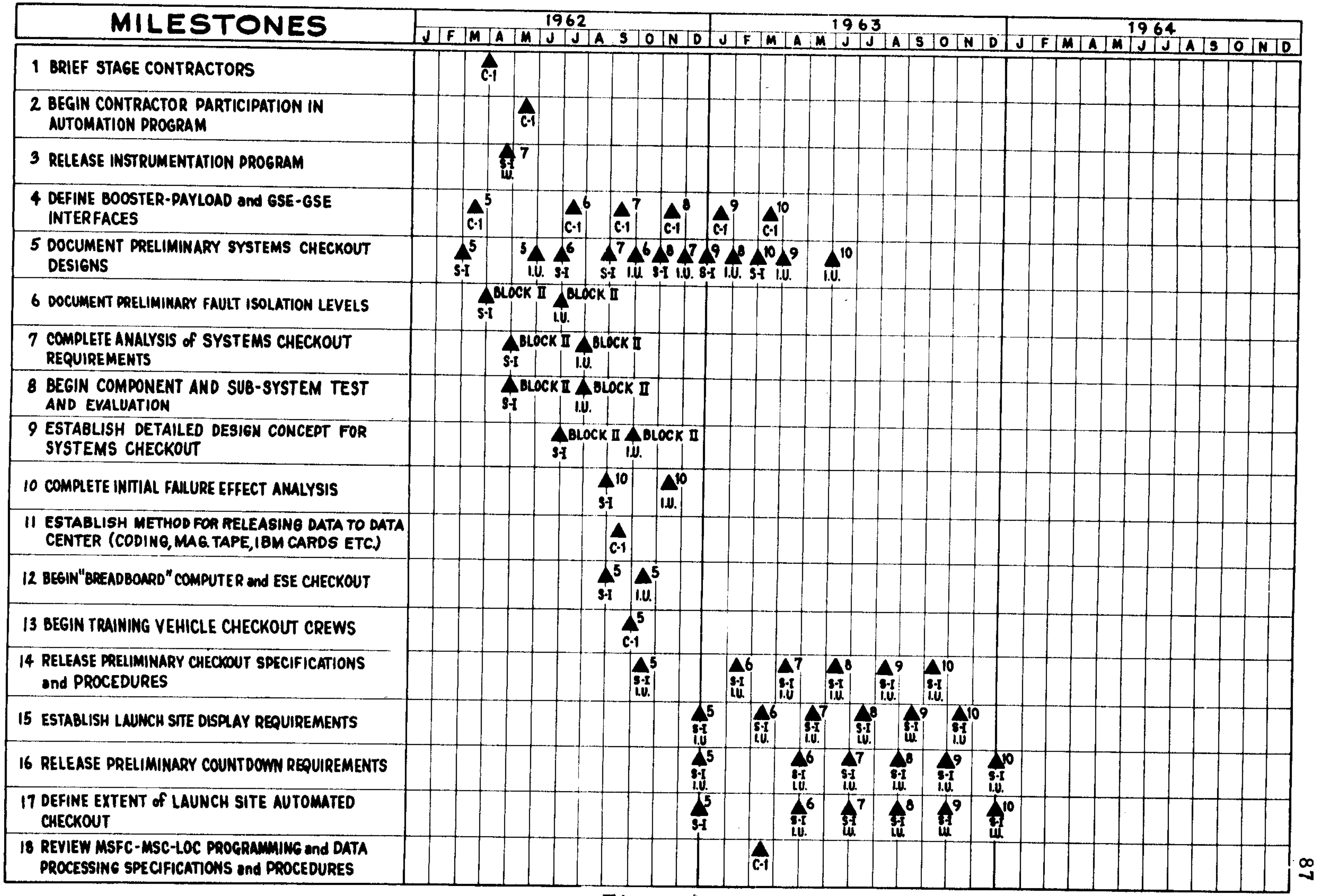


Figure 47.

C-1 AUTOMATIC CHECKOUT SYSTEMS DEVELOPMENT SCHEDULE

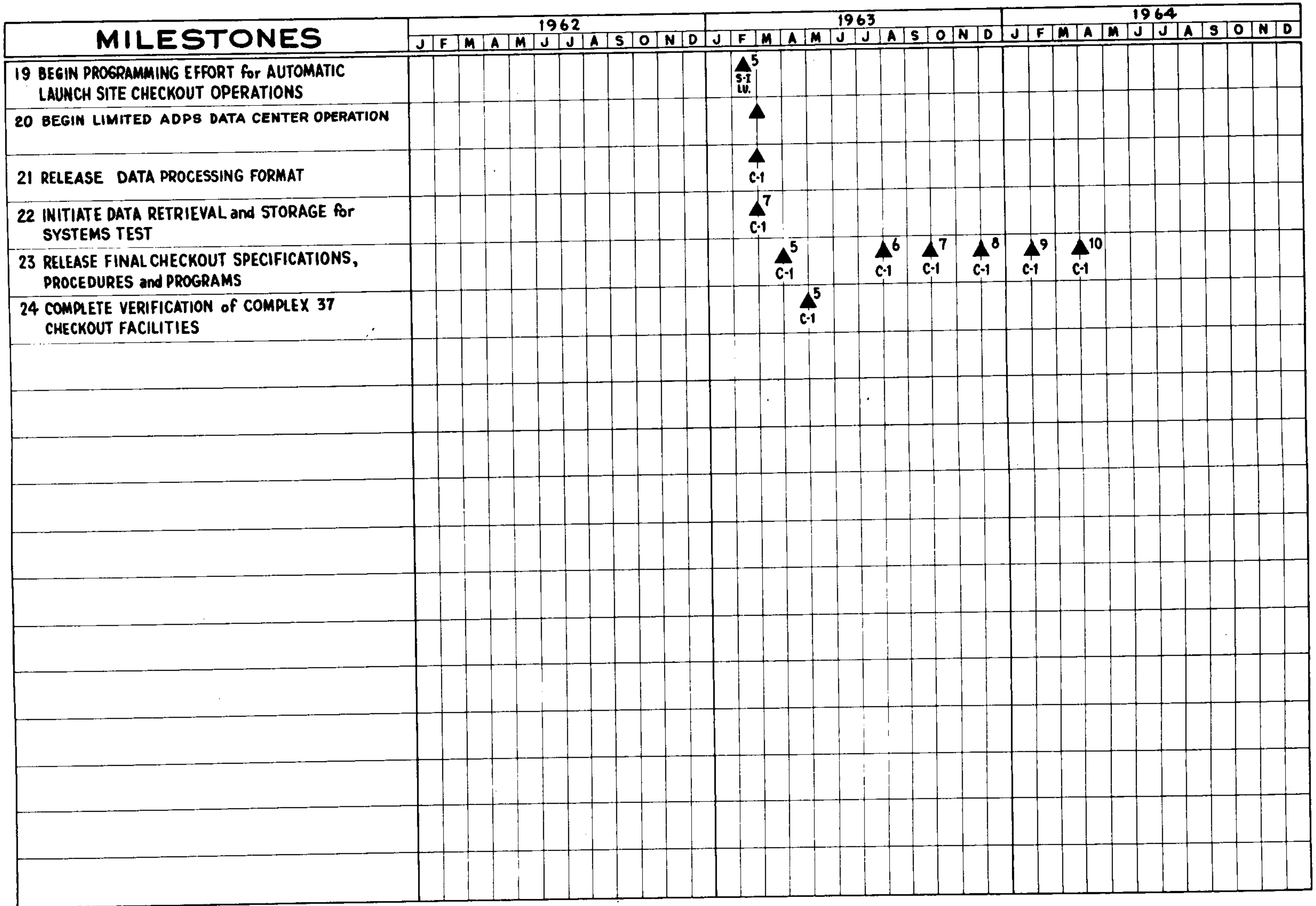


Figure 48.

C-5 AUTOMATIC CHECKOUT SYSTEMS DEVELOPMENT SCHEDULE

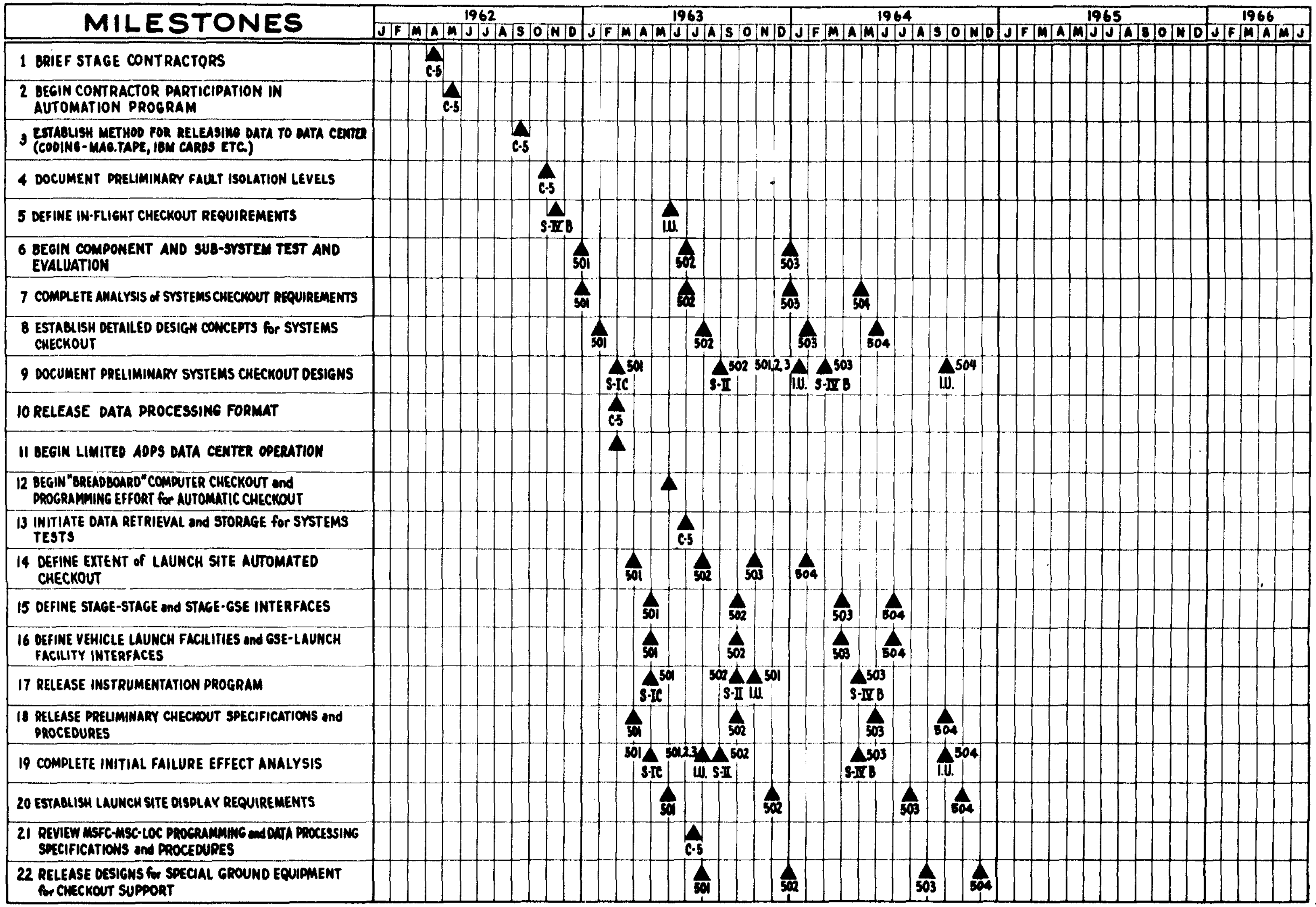


Figure 49.

C-5 AUTOMATIC CHECKOUT SYSTEMS DEVELOPMENT SCHEDULE

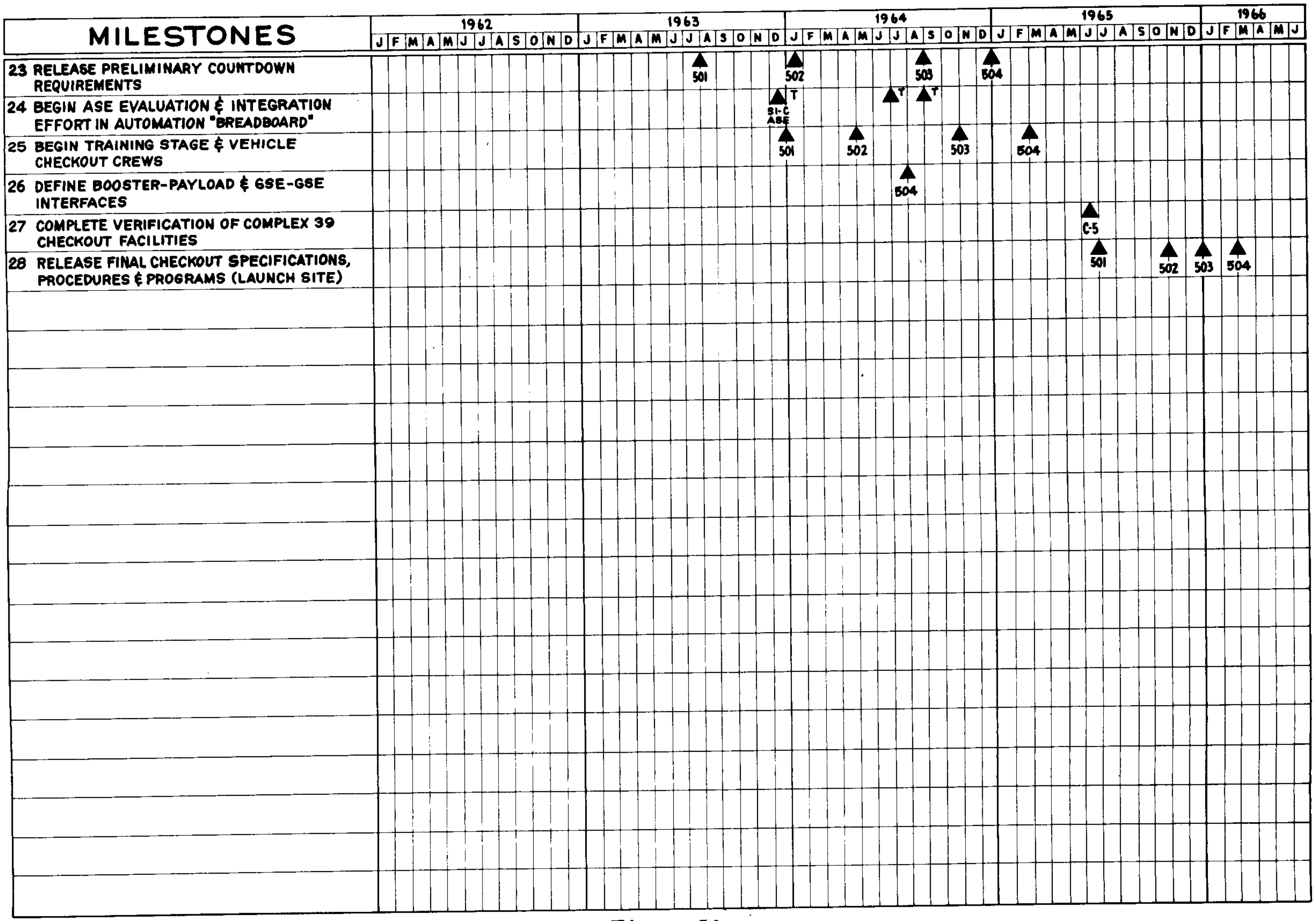


Figure 50.

a. Document Preliminary Systems Checkout Designs — Release preliminary documentation for designs based on the previous concepts.

b. Complete Analysis of Systems Checkout Requirements — Complete analyses carried out by design and launch operations personnel to determine the launch pad checkouts which must be carried out to assure launch vehicle operational readiness.

c. Begin Component and Subsystem Test and Evaluation — Begin vehicle and GSE component and subsystems tests relating to the development of proven automated checkout methods. Evaluate results.

d. Establish Detailed Design Concepts for Systems Checkout — Determine detailed concepts by which vehicle and ground systems will be designed to meet the checkout requirements established.

e. Complete Initial Failure Effect Analysis — Complete preliminary, but nevertheless detailed, analyses of the effects on vehicle operation of component and subsystem failures at critical operating periods.

f. Define Extent of Launch-Site Automated Checkout — Specify extent of automated checkout on launch pads based on automation "breadboard" tests, on analyses of launch pad checkout requirements, and on results of exhaustive feasibility studies.

g. Release Designs for Special Ground Equipment for Checkout Support — Release documentation for procurement or fabrication of special electrical and mechanical test adapters and other apparatus for supporting automated launch operations.

h. Establish Methods for Releasing Data to Data Center — Establish information recording methods to be used in transmitting test and checkout information via magnetic tape or IBM cards, etc., to and from the Data Center. The data retrieval coding system will be included in this category.

i. Release Data Processing Format — Release standardized input-output format by which information such as test numbers, part numbers and nomenclature, sequences of information printout, data coding and identification, etc., will be processed for the Data Center.

C. RESPONSIBILITIES OF THE MSFC AUTOMATION BOARD, ITS TECHNICAL STAFF, AND THE AUTOMATION SUBBOARDS.

As was pointed out earlier, another document will be released in the near future to describe the organizational responsibilities, control procedures, and other detailed information pertaining to the implementation of the MSFC Automation Plan. The document will be published after the operational relationships between MSFC and the new Launch Operations Center at Cape Canaveral have been determined.

From the standpoint of organizational responsibilities in the automation program, the forthcoming organizational realignments will principally affect checkout operations at Cape Canaveral. Responsibilities for vehicle and GSE development will not be markedly altered. Therefore, little change will occur in existing MSFC-stage contractor working relationships. Current arrangements for contractor direction by MSFC's line organizations will continue in effect. The MSFC Automation Board, its technical staff, and subboards will not participate in the direction of contractors.

The Automation Board was established by the Director, George C. Marshall Space Flight Center, to assure that comprehensive procedures are advanced and pursued for developing fully automated checkout and launch control systems for large space vehicles. The concepts documented in Section I of this report largely fulfill the first of the two missions. The second will be a continuing task which is described in the remainder of this section.

The Automation Board, which functions as a center-wide engineering council for systems integration and automatic checkout operations, is composed of key personnel from the MSFC divisions concerned with designing, checking out, testing, and launching space vehicles. The Saturn System Office is represented, as is the Manned Spacecraft Center. Because of the essential roles that Automation Board members play in their respective line organizations, they cannot devote full time to their Automation Board duties. Therefore, the staff of technical assistants to the Automation Board Chairman will assist the members of the board in assuring for the Director that comprehensive procedures are being pursued in the developments of automated checkout systems. Close follow-up is necessary to assure that vehicle stages designed and fabricated at the stage contractors' facilities will be compatible with vehicle checkout equipment and launch facilities to be furnished by NASA organizations or still other contractors.

The technical staff serves the Automation Board in advisory and coordinating capacities. A major responsibility assigned by the board's chairman is to continuously document steps being taken to adapt launch vehicles and their associated GSE to automated checkout and launch operations. While the members of the staff may serve as ex-officio members of MSFC-contractor working groups (at the discretion of the respective working group chairmen), they will not direct contractor activities. They are, however, authorized to independently monitor contractor activities that pertain to systems integration and checkout.

The Automation Board Staff, which is administratively, but not functionally, assigned to the Astrionics Division, will work closely with MSFC divisions as well as the contractors to continuously stay abreast of developments in the implementation phase of the automation program. To adequately document developments and to be of maximum service to line organizations, the staff will work with the design, checkout, and test engineers who are closely engaged in activities related to the technical responsibilities of the five automation subboards.

Each of the five technical assistants on the Automation Board will serve as the chairman of one of the subboards. The subboards are presently composed of highly qualified technical personnel from the organizations represented on the Automation Board. Contractor personnel are expected to begin participating in subboard activities in May 1962. Typical objectives of the subboards are:

a. To determine which of the components and flight systems of the space vehicles under development (or to be developed) by MSFC can be checked out automatically during operations at fabrication sites, at captive test sites, at launch sites, and during orbital operations. Launch-site checkouts will be further broken down into operations carried out prior to assembly of individual stages into vehicles and to operations carried out thereafter.

b. To establish and document detailed concepts by which vehicle and ground support systems can be designed or adapted to carry out necessary automatic checkout and launch control operations, once the components and flight systems to be automated are determined.

c. To establish schedules for developing, testing, and bringing into operational readiness automated checkout and launch control systems on time and funding bases compatible with MSFC vehicle development schedules.

d. To define (not assign) missions and responsibilities within MSFC and among MSFC's contractors in order that the previous objectives can be reached.

Other responsibilities of the automation subboards include:

a. The presentation of systems development and operation concepts to the Automation Board for its approval.

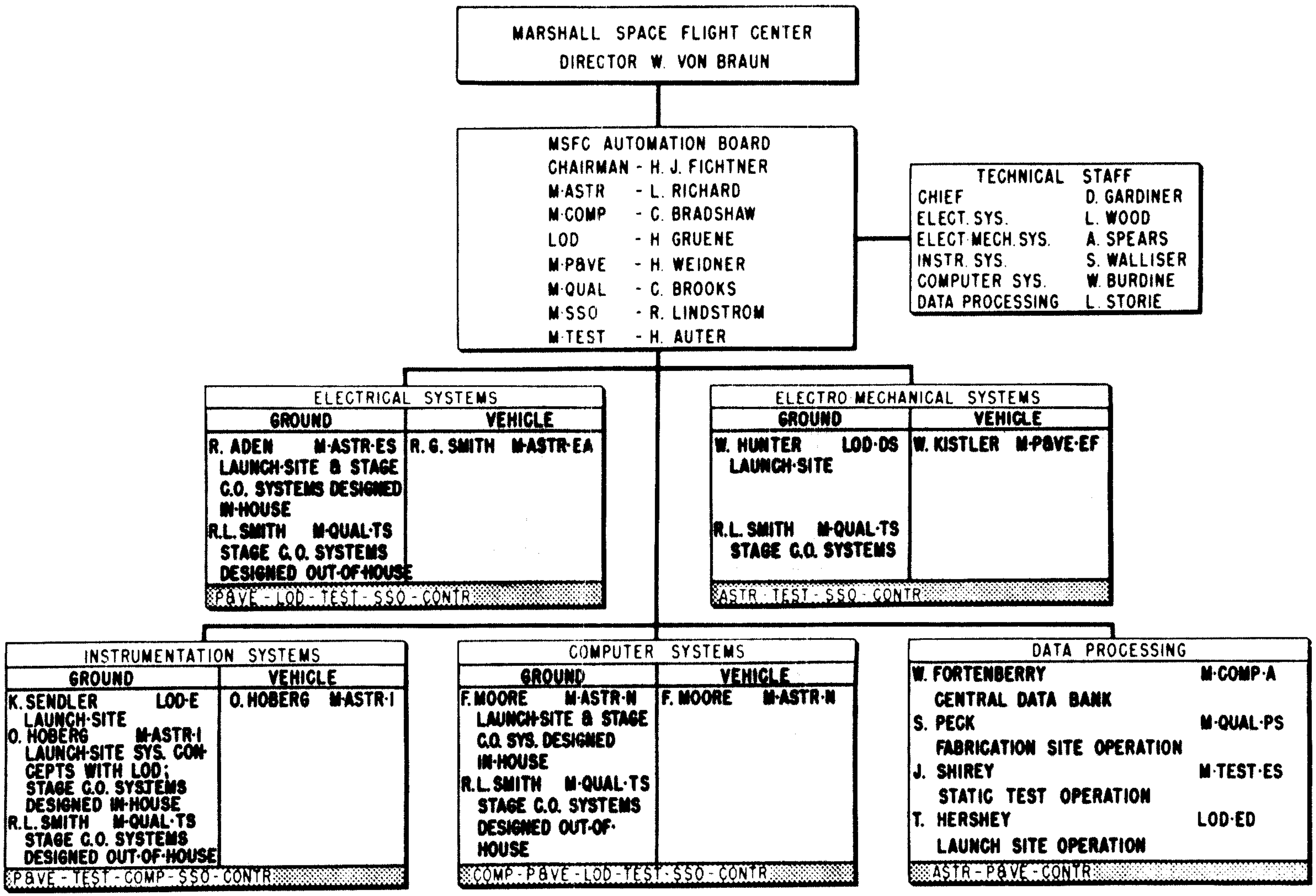
b. The distribution and clarification within line and project management organizations of approved automation concepts.

c. To report as required to the Automation Board on the progress being made in the development, testing, and operation of the systems primarily involved in automating stage and vehicle checkout operations.

The Director, MSFC, has designated the Chairman, MSFC Automation Board, as Marshall's authorized representative in transactions with the Director, Integration and Checkout, Office of Manned Space Flight, NASA. The Automation Board staff will assist the chairman in such transactions. Similar working relationships will exist between the Automation Board staff and the General Electric Company, which has been assigned certain systems integration and checkout responsibilities for the Apollo program.

Figure 51 depicts the present internal working relationships at MSFC between the Automation Board, its technical staff, and key line organization personnel.

MSFC ORGANIZATIONAL RESPONSIBILITIES FOR SYSTEMS INTEGRATION AND AUTOMATIC CHECKOUT



DEVELOPMENT RESPONSIBILITY

SUPPORT RESPONSIBILITY

Figure 51.

M-MS-G 28-6-62 MARCH 23,1962

H. J. Fichtner
Chairman, MSFC Automation Board